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ABSTRACT

This manual provides a basic core of instruction for both industrial electricity and industrial electronics. The information should be adapted and modified to coincide with local conditions and supplemented by the instructor's own methods and materials. The manual includes 6 sections (instructional areas) and 24 units. Each unit of instruction consists of eight basic components: performance objectives, teacher activities, information sheets (content essential for meeting the cognitive objectives), assignment sheets (applications of knowledges that are prerequisites to skill development), job sheets (procedures to complete a manipulative or psychomotor skill), transparency masters, tests, and test and assignment sheet answers. Section A, Orientation, contains three units: Introduction, Safety, and Hand Tools. The three units in section B, Electron Theory, are Atoms and Materials, Magnetism, and Batteries. Section C, Circuit Theory, includes four units: DC Fundamentals, Series-Parallel, Power, and AC Fundamentals. Meters and the Oscilloscope are the two units in section D, Test Instruments. The nine units in section E, Basic Electronic Components, are Resistors, Capacitors, Inductors, Transformers, Switches and Relays, Vacuum Tubes, Capacitance and Inductance, RC and RL Circuits, and Impedance and Resonance. Section F, Fabricating Skills, has three units: Basic Wiring Techniques, Soldering, and Printed Circuit Boards. (YLB)

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Introduction to Industrial Electricity - Electronics

OKLAHOMA TRADE AND INDUSTRIAL EDUCATION

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INTRODUCTION TO INDUSTRIAL ELECTRICITY - ELECTRONICS

TABLE OF CONTENTS

SECTION A--ORIENTATION

Unit I Introduction 1-A
Unit II Safety 39-A
Unit III Hand Tools 83-A

SECTION B--ELECTRON THEORY

Unit I Atoms and Materials 1-B
Unit II Magnetism 41-B
Unit III Batteries 89-B

SECTION C--CIRCUIT THEORY

Unit I DC Fundamentals 1-C
Unit II Series - Parallel 51-C
Unit III Power 113-C
Unit IV AC Fundamentals 157-C

SECTION D--TEST IINSTRUMENTS

Unit I Meters 1-D
Unit II Oscilloscope 83-D

SECTION E--BASIC ELECTRONIC COMPONENTS

Unit I Resistors 1-E
Unit II Capacitors 47-E
Unit III Inductors 117-E
Unit IV Transformers 153-E
Unit V Switches and Relays 241-E
Unit VI Vacuum Tubes 307-E
Unit VII Capacitance and Inductance 383-E
Unit VIII RC and RL Circuits 433-E
Unit IX Impedance and Resonance 483-E

SECTION F--FABRICATING SKILLS

Unit I Basic Wiring Techniques 1-F
Unit II Soldering 61-F
Unit III Printed Circuit Boards 131-F

4

FOREWORD

Today Industrial Maintenance teachers are faced with increasing problems of what to teach and whom to serve. The many different fields in Industrial Maintenance demand well-educated students who possess the information and skills needed for employment. During the task analysis of this manual, competencies needed for both Industrial Electricity and Industrial Electronics were identified and included in this manual. Further development is being done in the specialized areas of Industrial Electricity and Industrial Electronics.

The purpose of this manual is to provide a basic core of instruction for both Industrial Electricity and Industrial Electronics. Although the format reflects a systematic approach to instructional materials development, the information in *Introduction to Industrial Electricity-Electronics* should be adapted and modified to coincide with local conditions. To make the training process complete, it is intended that the materials be coupled with the instructor's own methods and experience.

Dr. Francis T. Tuttle, Director
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PREFACE

For many years a need has existed for an industrial training program directed toward the education of industrial oriented electrical-electronic personnel. Such a program was funded by the Oklahoma State Department of Vocational and Technical Education to begin a pilot program at Indian Meridian Area Vocational Technical School, Stillwater, Oklahoma.

Instructional material in this manual is written in terms of student performance, using measurable behavioral objectives. This is an innovative approach to teaching which accents and augments the teaching-learning process. Criterion-referenced evaluation instruments provide for a uniform measurement of student progress.

Industrial electricity-electronics instructors are faced with the challenge of providing students with the skills and related information necessary to meet the demands of a rapidly changing profession. Requirements for employment are more demanding than ever before. Therefore, industrial electricity-electronics technicians must be more highly skilled in order to fill the many positions available to them. Not only do they require technical skills, but they need to know how to deal with the public and how to sell themselves and their abilities.

The purpose of this manual is to assist industrial electricity-electronics instructors in providing instruction throughout industry. This publication should be supplemented by each instructor's methods and materials. Any information in this manual that does not concur with the instructor's course of study can be easily modified to meet personal needs.

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USE OF THIS PUBLICATION

Instructional Units

Introduction to Industrial Electricity-Electronics includes six instructional areas (sections). A standard format was established in 1970 for the development of instructional materials for all Oklahoma vocational teachers. This format includes eight basic components which form a unit of instruction: performance objectives, suggested activities for the teacher, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to tests and assignment sheets. Depending on the specific objectives, transparency masters, assignment sheets, and job sheets may or may not be included in the unit of instruction.

All of the unit components "zero in" on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching-learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help him or her determine the following.

A. Amount of material that can be covered in each class period
B. Skills which must be demonstrated
  1. Supplies and equipment needed
  2. Amount of practice needed
  3. Amount of class time needed for demonstrations
C. Supplementary materials, such as pamphlets and filmstrips, that must be ordered
D. Resource people who must be contacted

Performance Objectives (white pages)

Each unit of instruction is based on the performance needed for successful employment in an occupational area. Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction, and specific objectives, stating the student performance necessary to reach the unit objective.

Because the objectives of the unit provide direction for the teaching-learning process, it is important that teachers and students have a common understanding of the intent of the objectives. Following is a list of performance terms, their meanings, and behavioral synonyms which may have been used in this material.

A. **Name**--The individual supplies a name for objects, events, or people

Behavioral synonyms: *Label, list, letter, record, reiterate, repeat, write*

B. **Identify**--The individual selects a named, described, or pictured object by pointing to it, touching it, picking it up, or selecting it

Behavioral synonyms: *Select, mark, match, choose, judge*

C. **State a rule**--The individual communicates a relationship or principle which could be used to solve problems or perform a task

D. **Apply a rule**--The individual supplies an answer to a problem by using a stated relationship or principle

Behavioral synonyms: *Solve, calculate*

E. **Describe**--The individual relates sufficient characteristics or properties of an object or event so that a second individual will be able to state what is being discussed

Behavioral synonyms: *Define, discuss, interpret, recite, tell how, tell what happens when*

F. **Distinguish**--The individual selects an object or event from two or more which are easily confused

Behavioral synonyms: *Discriminate, differentiate*

G. **Order**--The individual arranges three or more objects or events in a sequence based on a stated property

Behavioral synonyms: *Arrange, sequence, list in order, classify, divide, isolate, sort*

H. **Construct**--The individual makes a physical object, a verbal statement, or a drawing

(NOTE: *Construct* is used when the finished product or result is important.)

Behavioral synonyms: *Draw, make, build, design, formulate, reproduce, transcribe, convert, put together, compile*

I. **Demonstrate**--The individual performs several operations necessary to carry out a specified process

(NOTE: *Demonstrate* is used when it is desirable to watch the student perform a task, one of the highest levels of student performance.)

Behavioral synonyms: *Show your work, show procedure, perform an experiment, perform the steps, operate, remove, replace, turn off/on, (dis) assemble, (dis) connect*

The objectives should be provided for students and stressed throughout the teaching-learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Prepare for each unit by deciding how each objective can best be taught.

The objective sheet may be also used as a quick pretest to determine prior knowledge of students and to determine whether further study or activities are necessary. Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When changes in objectives are made, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion test items.

Suggested Activities (pink pages)

This component is included only in teacher material. The suggested activities page assists teachers during the preparation stage of the teaching-learning process by providing suggestions for delivery and/or presentation during the instructional process. Read the suggested activities before teaching the units so that supplemental materials can be obtained, audiovisual materials prepared, and outside resources contacted. Duties of the teacher will vary according to the particular unit.

The references that are listed are ones used in the development of each unit. They should be used by the teacher to supplement knowledge of the subject area or to help students with particular interests or occupational objectives in the area covered.

Information Sheet (green pages)

The information sheet provides "must know" content essential for meeting the cognitive (knowledge level) objectives of the unit. The information is written in a topical outline form and is keyed to the specific objectives.

Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. The information sheet may also be used for coordination activities and advisory committees.

Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide motivation for each unit.

Transparency Masters (white pages in teacher material and green in student material)

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheet. They are particularly effective when indentification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. It is recommended that teachers stand away from the overhead projector when duscussing transparency material to avoid speaking too loudly.

Assignment Sheets (brown pages)

Assignment sheets give students a chance at problem solving, self-assessment, and/or practical experience with the information. They assist students in the application of knowledges which are necessary prerequisites to skill development. Assignment sheets may be given to the student for completion in class or used for homework assignments. Answer sheets are provided, when appropriate, and can be used by the student and/or teacher for checking student progress.

Job Sheets (blue pages)

Job sheets are another important segment of a unit of instruction. The job sheets provide a list of equipment, tools, and materials needed to complete a manipulative or psychomotor skill. They describe a step-by-step procedure needed to complete each task or job. Diagrams, photographs, and illustrations are provided to assist students in achieving the skill.

A teacher should demonstrate to students the procedures outlined in each job sheet. Furthermore, the teacher needs to localize the job sheet according to the equipment and supplies available in the local lab or shop situation. Job sheets also furnish potential employers with a picture of the skills being taught and the performances they might reasonably expect from a person who has had this vocational instruction.

Tests (yellow pages)

This component provides criterion-referenced evaluation of every objective listed in the unit of instruction. It is crucial to note that both paper/pencil and performance objectives must be evaluated.

The tests may be written or oral. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of questions from the units covered may be used for final tests at the end of each term if desired. If objectives have been added, deleted, or modified, be sure to make the changes on the test.

The acceptable response on a unit test--eighty-five percent in most units--may be raised or lowered to fit the topic or students' ability levels. The percentage applies to the overall score, not to each question. The final unit grade should be obtained by using the paper/pencil score along with teacher evaluations of student demonstrations of the desired skills.

Answers to Test and Assignment Sheets (pink pages)

These components are designed to assist the teacher in evaluation of student performances.

Page Numbering

Each publication from the Curriculum and Instructional Materials Center is assigned a specific abbreviation. For example, *Introduction to Industrial Electricity-Electronics* has been abbreviated. The units are then numbered consecutively within each section. An example of a page number is IIEE-1-A. Because CIMC publications are loose-leaf, this system of page numbering was adopted so that pages from different manuals would not get mixed up.

Methods of Disseminating Material

To keep the material before the students always new, material may be given out a unit or page at a time. Each unit is then placed in the larger binders upon its completion. The large binders may be purchased at cost from the CIMC. Some teachers have stored the materials by units in filing cabinets or boxes until needed for use. All the units may be given out at once if desired.

For best results, student materials should be provided for each student. Student materials contain everything but the test answers, answers to assignment sheets, and suggested activities. The tests are collated at the back of student material and should be removed and stored until needed. Students should be allowed to take their materials home.

Teaching Methods

It is a challenge to keep students motivated. Supplement the objectives by providing the "why," personal experiences, and current information. Prepare for each unit by deciding how each objective can be taught best. Allow students to become involved in preparing and planning.

INTRODUCTION
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to list factors concerning the occupation and occupational outlook for industrial maintenance workers. This knowledge will be shown by completing assignment sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with industrial maintenance to their correct definitions.
2. Name factors concerning the occupational outlook for industrial maintenance technicians.
3. Name employment opportunities for industrial maintenance technicians.
4. Distinguish between advantages and disadvantages of an industrial maintenance career.
5. State characteristics of a good industrial maintenance technician.
6. Name major skills involved in industrial maintenance.
7. Complete a general mathematics quiz.
8. Write a resume.
9. Complete an employment application.
10. Practice interview questions.
11. Compare job opportunities.

INTRODUCTION
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Discuss unit and specific objectives.

   D. Discuss information sheet.

   E. Demonstrate and discuss procedures outlined in assignment sheets.

   F. Give students tour of school, including both I-E/E program and other programs available in school.

   G. Inform students of competition results from previous years.

   H. Inform students of various achievements of past students.

   I. Show students articles and films, and give students demonstrations and tours of opportunities available to graduates.

   J. Give test.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Assignment sheets

      1. Assignment Sheet #1--Complete a General Mathematics Quiz

      2. Assignment Sheet #2--Write a Resumé

      3. Assignment Sheet #3--Complete an Employment Application

      4. Assignment Sheet #4--Practice Interview Questions

      5. Assignment Sheet #5--Compare Job Opportunities

SUGGESTED ACTIVITIES

E. Answers to assignment sheets

F. Test

G. Answers to test

III. Unit references

A. Cooke, Nelson M. and Herbert F.R. Adams. *Basic Mathematics for Electronics*. 4th ed. New York: McGraw-Hill Book Company, 1976.

INTRODUCTION
UNIT I

INFORMATION SHEET

I. Terms and definitions

   A. Industrial maintenance--Occupation involving the troubleshooting, repairing, and maintenance of industrial equipment

   B. Skills--Abilities gained by special experience

   C. Job--Work done in return for pay

   D. Electricity--Science which pertains to large amounts of current flowing through devices, circuits, or systems

   E. Electronics--Science and engineering concerned with the behavior of electrons in devices, and the utilization of such devices

   F. Industrial--Any branch of trade, production, or manufacture, or a combination of all

   G. Vocational Industrial Clubs of America (VICA)--Organization of students and advisors enrolled in trade and industrial and technical education at local, state, and national levels

      (NOTE: This is commonly abbreviated and called *VICA*.)

   H. Hydraulics--Use of liquids or fluids in engineering

   I. Pneumatics--Use of air or other gases in engineering

   J. Mechanical--Use of machinery and gears in engineering

II. Factors concerning the occupational outlook for industrial maintenance technicians

   A. Job opportunities result each year from the need to replace experienced technicians who retire or die

   B. More and larger industries are constructed each year, requiring more technicians

      EXAMPLES: Space travel, computerized machines, computerized cars, oil exploration

   C. Specialization creates more job opportunities and more desirable working conditions

   D. New designs and modern techniques make industrial maintenance more desirable

   E. New and larger equipment opens new fields in maintenance and repair

   F. Conservation and recycling creates more jobs

INFORMATION SHEET

III. Employment opportunities for technicians (Assignment Sheets #1, #2, and #3)

- A. Industrial plant maintenance
- B. Medical equipment maintenance
- C. Computer maintenance
- D. Additional education
- E. Office equipment maintenance
- F. Space technology
- G. Military

IV. Advantages and disadvantages of an industrial maintenance career

- A. Advantages
    1. Good pay and benefits
    2. Inside work
    3. Variety of jobs
    4. Improvement of skills

       EXAMPLE: Maintenance on different types of equipment
    5. Increased job mobility

       (NOTE: A technician with several skills has opportunity to work in other geographic locations.)
- B. Disadvantages
    1. Dirty
    2. Hazardous
    3. Have to wear safety equipment

       EXAMPLES: Safety glasses, dust respirators, safety shoes, and hard hats

V. Characteristics of a good industrial maintenance technician

(NOTE: It is impossible to cover every phase of safety and hazardous conditions; therefore, knowledge and adaption to basic rules will help develop good and safe habits.)

- A. Checks all equipment before starting work
- B. Operates all equipment correctly

INFORMATION SHEET

- C. Is safety conscious and follows safety regulations
- D. Takes instructions readily and follows company rules
- E. Practices conservation of materials and equipment
- F. Shows enthusiasm for job
- G. Exhibits pride in the trade
- H. Controls temper at all times
- I. Is punctual
- J. Is a good citizen

VI. Major skills involved in industrial maintenance

- A. Mathematical ability
- B. Color perception
- C. Manipulative skills with small components
- D. Troubleshooting

INTRODUCTION
UNIT I

ASSIGNMENT SHEET #1--COMPLETE A GENERAL MATHEMATICS QUIZ

NAME____ SCORE ____________________

During your training in the I-E/E program, certain mathematical knowledge is necessary. This quiz is designed to give both the student and the teacher a view of the student's mathematical knowledge.

Complete the following mathematics quiz. Write your answers in the spaces provided.

A. Add the following equations

$$1.\ \begin{array}{r} -8 \\ \underline{-3} \end{array} \qquad 2.\ \begin{array}{r} -16 \\ \underline{+8} \end{array} \qquad 3.\ \begin{array}{r} 250 \\ \underline{-125} \end{array} \qquad 4.\ \begin{array}{r} -408 \\ \underline{206} \end{array} \qquad 5.\ \begin{array}{r} 3.65 \\ \underline{-4.42} \end{array}$$

B. Subtract the following equations

$$1.\ \begin{array}{r} +12 \\ \underline{+5} \end{array} \qquad 2.\ \begin{array}{r} +12 \\ \underline{-7} \end{array} \qquad 3.\ \begin{array}{r} -9 \\ \underline{12} \end{array} \qquad 4.\ \begin{array}{r} -256 \\ \underline{125} \end{array} \qquad 5.\ \begin{array}{r} -7.56 \\ \underline{2.21} \end{array}$$

C. Multiply the following equations

$$1.\ \begin{array}{r} 4 \\ \underline{-5} \end{array} \qquad 2.\ \begin{array}{r} -5 \\ \underline{-6} \end{array} \qquad 3.\ (-4)\,(4)\,(-4) =$$

$$4.\ (-3)\,(-4)\,(-5) = \qquad 5.\ (.003)\,(-15) =$$

ASSIGNMENT SHEET #1

D. Divide the following equations

1. $\frac{4}{2}$ 2. $\frac{-6}{-3}$ 3. $\frac{-44}{4}$ 4. $\frac{36}{6}$ 5. $\frac{225}{-5}$

E. Express the following as numbers between one and ten with the correct power of 10.

1. 8,400,000 = ________
2. .0125 = ________
3. .00000058 = ________
4. 4,582 = ________
5. 45,000 = ________

F. Convert the following powers of ten to whole numbers.

1. 4.83×10^{-4} = ________
2. 1.6×10^{1} = ________
3. 6.28×10^{5} = ________
4. 4.62×10^{-6} = ________
5. 1.2×10^{7} = ________

G. Add the following powers of ten, and express in powers of 10.

1. $(12 \times 10^{3}) + (6 \times 10^{3})$ = ________
2. $(8 \times 10^{3}) + (2 \times 10^{4})$ = ________

H. Subtract the following powers of ten, and express in powers of 10.

1. $(6.28 \times 10^{1}) - (.28 \times 10^{1})$ = ________
2. $(1.3 \times 10^{-3}) - (3 \times 10^{-4})$ = ________

I. Multiply the following powers of ten, and express in powers of 10.

1. $(8 \times 10^{3})(6 \times 10^{3})$ = ________
2. $(4.2 \times 10^{2})(5 \times 10^{8})$ = ________

ASSIGNMENT SHEET #1

J. Divide the following powers of ten, and express in powers of 10.

1. $(100 \times 10^6) \div (10 \times 10^6) =$ ______________________
2. $(36 \times 10^1) \div (.06 \times 10^4) =$ ______________________

K. Calculate the following terms

1. $5^2 =$ ______________________
2. $36^2 =$ ______________________
3. $8^3 =$ ______________________
4. $12^3 =$ ______________________
5. $14^2 =$ ______________________

L. Find the square root of the following numbers

1. 144 = ______________________
2. 1156 = ______________________
3. 5184 = ______________________
4. 497.29 = ______________________
5. .2025 = ______________________

M. Transpose the following equations as indicated

1. $T = \frac{1}{f}$ $f =$ ______________________
2. $A = B + C$ $C =$ ______________________
3. $I = \frac{E}{R}$ $R =$ ______________________
4. $E_a = E_R^2 + E_L^2$ $E_R =$ ______________________
5. $X_L = \frac{L}{C}$ $L =$ ______________________

N. Solve the following equations

1. $(X^2) + (X^2) =$ ______________________
2. $(25X + 3Y) - (15X - 7Y) =$ ______________________
3. $(X^4)(X^3) =$ ______________________
4. $(20X^4 Y^6) \div (5X^2 Y^2) =$ ______________________

ASSIGNMENT SHEET #1

O. Solve the following equations for the unknown value

1. $3X - 6 = 6$ X = ______________________________
2. $5M + 2 = 3 + 4M$ M = ______________________________
3. $\frac{X}{3} = \frac{4}{2}$ X = ______________________________
4. $\frac{4}{2} = \frac{K}{6}$ K = ______________________________

P. Convert the following values as indicated

1. 6000 = ____________________ kilo
2. 7000 milli = ____________________ kilo
3. 94 = ____________________ milli
4. 6 mega = ____________________ milli
5. .01 kilo = ____________________ milli
6. .003 = ____________________ micro
7. 6 mega = ____________________ units

INTRODUCTION
UNIT I

ASSIGNMENT SHEET #2--WRITE A RESUMÉ

Write a resumé using accurate facts about yourself. Include the resumé with a letter of application. Use the information below and the sample resumé included in this assignment sheet as guides.

A good resumé should immediately give prospective employers a brief summary of your accomplishments, educational background, work experience, skills, and job objective. It is not necessary to use the exact wording and outline form used on the sample resumé, but it is necessary that your resumé be neat and balanced and contain all the information which might help you get a job. Keep a current copy of your resumé and use it to apply for jobs.

A. Inspect several resumé formats and choose one that best fits your needs, or use as a guide the example included in this assignment sheet.

B. Type your resume on 8 1/2 x 11 inch white paper. Try not to exceed one page, but attempt to fill the page.

C. Spell correctly. Many employers will not consider people whose resumés contain misspelled words.

D. Put your name prominently at the top, in the center or upper left-hand corner. Beneath your name, give your full street address, city, state, zip code, telephone number with area code, and a number where messages can be accepted.

E. Do not include birthplace, age, health, height, weight, sex, marital status, photo, salary, or reasons for leaving previous job; avoid listing religious and political affiliations.

(NOTE: In general, the more information you are willing to share the better. The whole point of a resumé is to interest employers in meeting you in person. At your descretion, the personal information above may or may not be revealed in the interview. However, by not including this information there is little chance for discrimination because of race, color, religion, sex, or national origin.)

F. Describe your job objective or career goal briefly; do not restrict yourself to a specific job unless you are experienced.

G. Describe your educational background, giving dates of enrollment, diploma or degrees received, and names of schools attended. Include grade average (if favorable) and major courses of study. If you include school grades, be sure they are related to the jobs you have in mind.

(NOTE: Applicants with less than one year of work experience should list education *before* work experience. In resumé writing, accentuate the positive. If pertinent, mention additional courses, scholarships, or summer school.)

ASSIGNMENT SHEET #2

H. List your past employment, starting with your most recent job. Carefully examine all of your jobs--including job-related extracurricular activities.

(NOTE: The list should include the name of the company, your job title, and your major duties. The starting and termination dates for each job should also be listed. Most employers ask during interviews why you left previous jobs. Try to be positive in stating your reasons for leaving a former job. Do not downgrade your previous employers.)

I. List skills useful to the job for which your are applying. Remember, you have to prove your value to the business, especially if you have little experience.

(NOTE: Use active verbs to indicate the specific tasks you performed, e.g., *built, assisted, operated*.)

J. Include the following information if it is relevant and if there is enough space: hobbies and interests, extracurricular activities, clubs, and awards you have received.

K. List at least three persons as references; ask yourself the kinds of recommendations they will give you

EXAMPLES: Business references, teachers, character references

(NOTE: Avoid listing relatives unless you have actually worked for them on a salary basis. Include the person's title and business address so that the prospective employer may acquire references.)

L. Write "Confidential" at the top of the resume if you don't want your current employers to know that you are looking for employment.

M. Have a local printer or word processor retype your resumé and reproduce several copies. Request white bond paper.

(NOTE: Your resumé's physical appearance is *very important*. Avoid using ditto or carbon copies. Be sure to proofread the printer's work. Always bring extra copies to the interview. Leave one copy of your resumé with interviewer, and use one as a reference when filling out the application form. You should also mail one resumé with your letter of application.)

ASSIGNMENT SHEET #2

SAMPLE RESUMÉ

Terry McKracken

Address:

Present
774 E. Adams Street
Yourtown, Yourstate 77704
405-311-7779

Permanent
Route #3
Anytown, Yourstate 77702
405-235-4433

(NOTE: You may ask printer to leave space for you to fill in address if you are moving.)

Job Objective: Career in the industrial maintenance field leading to supervisory position in this field

Education: Anytown High School, Anytown, Yourstate 1975-1979

Progress Vo-Tech, Progressville, Yourstate 1979
Certificate: Industrial Electricity, four semesters
Grade average: 3.5 on a 4.0 scale

Subjects Studied:
Vocational industrial electricity--Two years (1080 hours)
Algebra--Two semesters
Geometry--Two semesters
Basic drafting--Two semesters
Industrial arts woodworking--Two semesters

Student Activities:
President, Senior Class
President, VICA
Treasurer, Baptist Youth Fellowship Organization
Industrial Electricity Contest--First Place State, Third Place Nation

Work Experience:
Electrician's helper--Jones Construction Company, Summer 1979
Vocational Industrial Electricity Class 1977-78--All phases of construction wiring

References:

Mr. Sammy Slavedriver
Vocational Industrial Electricity Instructor
Progress Vo-Tech
Progressville, Yourstate 77703

Mrs. Jerri Smith
Youth Director
Parkview Baptist Church
711 Fellowship Circle
Anytown, Yourstate 77702

Mr. John Naildriver
Construction Supervisor
Jones Construction Company
Anytown, Yourstate 77702

INTRODUCTION
UNIT I

ASSIGNMENT SHEET #3--COMPLETE AN EMPLOYMENT APPLICATION

NAME ______________________ SCORE ______________

Complete the following application form using the guidelines below and personal information about yourself, your education, and your work experience.

(NOTE: Although each business uses its own form, general rules of preparation apply to any form.)

A. Be prepared.

   1. Take a good ink pen.

   2. Take copies of resumé.

B. Look over entire form before starting to write; do not hurry.

C. Follow directions.

   1. Note whether information is to be printed or written.

   2. Carry out all directions.

D. Write clearly, neatly, and legibly.

E. Answer briefly.

F. Be honest.

G. Answer all questions.

   (NOTE: If questions do not apply to you, write *NOT APPLICABLE* or N/A in the space to show that you did not overlook the question.)

H. Include complete information.

I. Recheck application when finished.

J. Avoid cross-outs and erasure marks.

K. Use the word *open* for questions about minimum salary; most employers pay standardized rates and will not negotiate on this.

ASSIGNMENT SHEET #3

APPLICATION FOR EMPLOYMENT

DATE ____________

Name ______________________________ SS # ______ ______
(Last) (First) (Middle)

Present address ______________________________ Telephone # ______ ______
Street Address City

Phone where you can be reached if not at above number Telephone # ____________

Are there any periods during the year when you will not be available for work? Yes ____ No ____ When? ____________

What is the earliest date you will be available to start work? ____________

Are you licensed or certified by any trade or profession? Yes ____ No ____ Kind of License? ____________

Have you worked for the State Department of Vocational and Technical Education before? Yes ____ No ____ When? ______

How did you hear of employment opportunities at Vo-Tech?

____Self-referral
____Advertisement
____Friend or Relative
____Employment Agency
____Other

Position Desired: First preference will be given first consideration

1. ____________
2. ____________
3. ____________

Is there a minimum salary acceptable? Yes ____ No ____ If yes, what amount? ______

How long do you wish employment? Years ____ Months ____

I will accept:
Full-time ____ Part-time ____ Temporary ____ (6 mos. or less)

If part-time, what hours can you work? ______
____
____

How do you feel you are qualified for the position(s) applied for?

____
____
____
____

EDUCATION: List in order the educational institutions you have attended if applicable

Dates		Name of Institution	Major & Minor Courses Pursued	Degree or Certificate
From	To			
High School				
College or Univ.				
Vocational, Technical or Trade Schools				

[illegible]

ASSIGNMENT SHEET #3

May we contact your present Employer for References? ________

Employer ____________________ (Present or Most Recent) Address ____________________ Street City State

Phone ____________

Name and title of supervisor ____________________ From Month ________ Year ________

Your job and description of duties ____________________ To Month ________ Year ________

____________________ Pay $ ________ Per ________

Reason for terminating this Employment ____________________

Employer ____________________ Address ____________________ Street City State

Phone ____________

Name and title of supervisor ____________________ From Month ________ Year ________

Your job and description of duties ____________________ To Month ________ Year ________

____________________ Pay $ ________ Per ________

Reason for terminating this Employment ____________________

Employer ____________________ Address ____________________ Street City State

Phone ____________

Name and title of supervisor ____________________ From Month ________ Year ________

Your job and a description of duties ____________________ To Month ________ Year ________

____________________ Pay $ ________ Per ________

Reason for terminating this Employment ____________________

REFERENCES

1. ____________________ Name Address Phone
2. ____________________ Name Address Phone
3. ____________________ Name Address Phone
4. ____________________ Name Address Phone
5. ____________________ Name Address Phone

The above information is requested to become acquainted with your qualifications and IS NOT an offer of employment.

I certify that all of the information stated in this application is true to the best of my knowledge and belief, and I authorize you to refer to any former employers or others to verify the statements made.

____
Signature

EQUAL OPPORTUNITY EMPLOYER

The Oklahoma State Department of Vocational and Technical Education does not discriminate on the basis of race, creed, color, national origin, sex, age, veteran status, qualified handicap, or disability.

INTRODUCTION
UNIT I

ASSIGNMENT SHEET #4--PRACTICE INTERVIEW QUESTIONS

NAME ______________________________ SCORE ______________

The following are some questions which might be asked when applying for a job. Keep the assignment sheet to review before going to an interview.

(NOTE: Questions about your personal life may not legally be asked. In fact, it is illegal for an employer to ask your maiden name or your father's surname if you are a female applicant; your marital status; who lives with you; the church you attend or the name of your spiritual leader; how many children you have, their ages, or who will care for them while you are at work; whether you own or rent your residence; whether your have ever had your wages garnisheed; and whether you have ever been arrested. However, many interviewers, particularly in smaller businesses, may ask such questions. Whether or not you choose to answer the questions depends on how badly you want the job.)

A. Why did you leave your previous job?

____

____

B. What did you like best about your job?

____

____

C. Are you in good health?

____

____

D. Do you intend to make this work your career?

____

____

E. What are some of your special abilities?

____

____

ASSIGNMENT SHEET #4

F. What equipment can you operate?

G. How would you rate your training for this job? Very good? Fair?

H. What personal characteristics do you think are needed to succeed in your vocation?

I. At what salary do you expect to start?

J. How could you contribute to our organization?

K. Why should we hire you?

L. Tell us about your family and any plans for marriage or further education.

(NOTE: *Remember* that legally you do not have to answer this question. However, it is a good idea to have an answer.)

M. Have you applied for any other jobs?

ASSIGNMENT SHEET #4

N. Do you have any military obligations to fulfill?

____

____

O. Would you be able to work Saturdays and Sundays?

____

____

P. Does criticism disturb you?

____

____

Q. Would you be willing to relocate?

____

____

R. What size city do you prefer?

____

____

S. Define *cooperation*.

____

____

T. How do you feel about working overtime?

____

____

REMEMBER: You never get a second chance to make a good first impression. *Getting a job is a job!*

INTRODUCTION
UNIT I

ASSIGNMENT SHEET #5--COMPARE JOB OPPORTUNITIES

NAME ______________________________ SCORE ______________

When you are offered a job or are changing jobs, there are many factors to weigh before taking the position. Some of these include

What will be my take-home pay?

What are the benefits which accompany the job?

How much will it cost to actually be at work each day?

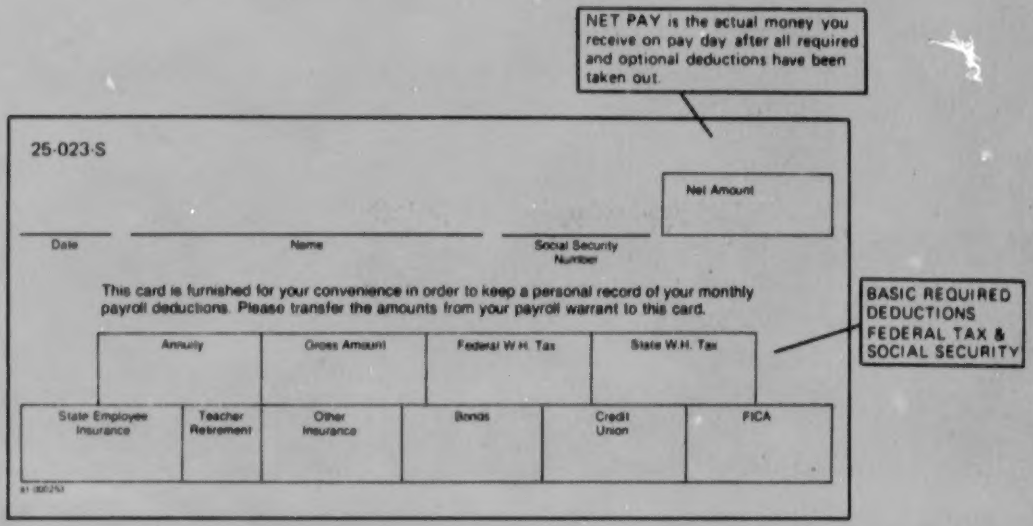
Will the job be satisfying to me?

How will the job meet my needs and aspirations?

WHAT WILL BE MY TAKE-HOME PAY?

Salaries and wages are often quoted by employers as *gross earnings*. Gross earnings are used because tax deductions vary due to number of dependents, amount of earnings, and other factors.

Optional benefits and deductions offered by an employer also differ. It is generally advisable to ask what programs are available as these can affect the actual money you receive on payday.



NET PAY is the actual money you receive on pay day after all required and optional deductions have been taken out.

25-023-S

Net Amount

Date ______ Name ______ Social Security Number ______

This card is furnished for your convenience in order to keep a personal record of your monthly payroll deductions. Please transfer the amounts from your payroll warrant to this card.

Annuity	Gross Amount	Federal W.H. Tax	State W.H. Tax

State Employee Insurance	Teacher Retirement	Other Insurance	Bonds	Credit Union	FICA

BASIC REQUIRED DEDUCTIONS FEDERAL TAX & SOCIAL SECURITY

ASSIGNMENT SHEET #5

WHAT OTHER BENEFITS WILL I GET FROM THE JOB?

Some benefits associated with working are not always visible. Often some of these overlooked benefits are paid for in part by your employer. At the time of the intervew, or when considering a position, ask about employer's contributions for your protectior which may include

- Health insurance
- Unemployment compensation
- Clothing and safety garments
- Medical facilities and health tests
- Pensions
- Travel insurance (covering mishaps when traveling on business)
- Educational programs or reimbursement for courses related to job.

Ask also about sick leave with pay, and paid vacations and holidays

WHAT WILL IT COST TO WORK AT THIS JOB?

Frequently, we often overlook the costs which are associated with being employed. It may be of value to calculate estimated weekly expenses before you make a decision about a job.

Estimated weekly expenses

Transportation (parking, bus fares) $____________

Lunches (or cost of food eaten away from home, including soft drinks and coffee) $____________

Clothing (including cleaning) $____________

Child care for working parent $__________

Gifts for other employees $__________

Special uniforms, materials, or equipment for job $__________

Other $__________

TOTAL $__________

ASSIGNMENT SHEET #5

WHAT IS IMPORTANT TO ME IN A JOB?

Take-home pay and benefits may be only part of what you want from a job. Think through other things you consider important in a job.

List some of the most rewarding aspects about any job you have ever held?

A. ____________________

B. ____________________

C. ____________________

How might you rate these in order of what is important to you?

_____ Job security (little chance you'll be released from the job)

_____ Opportunity for advancement

_____ Recognition for your work

_____ Good wages

_____ Opportunity to learn and use your ideas

_____ Flexible working hours

_____ Long vacations

_____ Pleasant working conditions

_____ Interesting work

_____ Friendly co-workers

_____ Other, such as ____________________

ARE YOU READY TO DECIDE?

Take all the information you have gathered and summarize it below and on the next page to reach a decision about whether or not you want the job.

A. Would the job be satisfying to me? Why or why not?

____

____

____

ASSIGNMENT SHEET #5

B. What are the benefits which accompany the job?

____

____

____

____

C. How much will it cost to actually be at work each day?

____

____

____

D. How will the job meet my needs and aspirations?

____

____

____

E. I estimate my take-home pay to be $__________.

F. I estimate my work-related expenses to be $__________.

G. I would most enjoy the following about this job:__________________

____

____

H. I estimate my job benefits to be worth $__________.

INTRODUCTION
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A.
1. −11
2. −8
3. 125
4. −202
5. −0.77

B.
1. 7
2. 19
3. −21
4. −381
5. −9.77

C.
1. −20
2. 30
3. 64
4. −60
5. −0.045

D.
1. 2
2. 2
3. −11
4. 6
5. −45

E.
1. 8.4×10^{6}
2. 1.25×10^{-2}
3. 5.8×10^{-7}
4. 4.582×10^{3}
5. 4.5×10^{4}

F.
1. .000483
2. 16
3. 628,000
4. .00000462
5. 12,000,000

G.
1. 1.8×10^{4}
2. 2.8×10^{4}

H.
1. 6×10^{1}
2. 1×10^{-3}

ANSWERS TO ASSIGNMENT SHEETS

I.
1. 4.8×10^{7}
2. 2.1×10^{11}

J.
1. 10×10^{0}
2. 6×10^{-1}

K.
1. 25
2. 1296
3. 512
4. 1728
5. 196

L.
1. 12
2. 34
3. 72
4. 22.3
5. 0.45

M.
1. $f = \frac{1}{T}$
2. $C = A - B$
3. $R = \frac{\text{[illegible]}}{I}$
4. $E_R = \sqrt{E_a - E_L{}^2}$
5. $L = CX_L$

N.
1. $2X^2$
2. $10X + 10Y$
3. X^7
4. $4X^2Y^4$

O.
1. 4
2. 1
3. 6
4. 12

P.
1. 6
2. .007
3. 94,000
4. 6,000,000,000
5. 10,000
6. 3,000
7. 6,000,000

Assignment Sheet #2--Evaluated to satisfaction of instructor

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #3--Evaluated to satisfaction of instructor

Assignment Sheet #4--Evaluated to satisfaction of instructor

Assignment Sheet #5--Evaluated to satisfaction of instructor

INTRODUCTION
UNIT I

TEST

NAME______________________ SCORE ______________

1. Match terms associated with industrial maintenance to their correct definitions. Write the correct numbers in the blanks.

_____a. Use of liquids or fluids in engineering

_____b. Any branch of trade, production, or manufacture, or a combination of all

_____c. Use of machinery and gears in engineering

_____d. Science and engineering concerned with the behavior of electrons in devices, and the utilization of such devices

_____e. Abilities gained by special experience

_____f. Work done in return for pay

_____g. Use of air or other gases in engineering

_____h. Organization of students and advisors enrolled in trade and industrial and technical education at local, state, and national levels

_____i. Science which pertains to large amounts of current flowing through devices, circuits, or systems

_____j. Occupation involving the troubleshooting, repairing, and maintenance of industrial equipment

1. Skills
2. Industrial maintenance
3. Mechanical
4. Vocational Industrial Clubs of America
5. Industrial
6. Pneumatics
7. Electricity
8. Electronics
9. Hydraulics
10. Job

2. Name factors concerning the occupational outlook for industrial maintenance technicians.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

TEST

3. Name employment opportunities for industrial maintenance technicians.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

4. Distinguish between advantages and disadvantages of an industrial maintenance career. Write an "X" in the blank before each advantage.

_____a. Improvement of skills

_____b. Have to wear safety equipment

_____c. Variety of jobs

_____d. Hazardous

_____e. Inside work

_____f. Good pay and benefits

_____g. Dirty

_____h. Increased job mobility

5. State six characteristics of a good industrial maintenance technician.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

TEST

6. Name major skills involved in industrial maintenance.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

(NOTE: Test questions 7 through 11 are assignment sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

7. Complete a general mathematics quiz.

8. Write a resumé.

9. Complete an employment application.

10. Practice interview questions.

11. Compare job opportunities.

INTRODUCTION
UNIT I

ANSWERS TO TEST

1. a. 9
   b. 5
   c. 3
   d. 8
   e. 1
   f. 10
   g. 6
   h. 4
   i. 7
   j. 2

2. a. Job opportunities result each year from the need to replace experienced technicians who retire or die
   b. More and larger industries are constructed each year, requiring more technicians
   c. Specialization creates more job opportunities and more desirable working conditions
   d. New designs and modern techniques make industrial maintenance more desirable
   e. New and larger equipment opens new fields in maintenance and repair
   f. Conservation and recycling creates more jobs

3. a. Industrial plant maintenance
   b. Medical equipment maintenance
   c. Computer maintenance
   d. Additional education
   e. Office equipment maintenance
   f. Space technology
   g. Military

4. a, c, e, f, h

5. Answer should include six of the following
   a. Checks all equipment before starting work
   b. Operates all equipment correctly
   c. Is safety conscious and follows safety regulations
   d. Takes instructions readily and follows company rules
   e. Practices conservation of materials and equipment

ANSWERS TO TEST

- f. Shows enthusiasm for job
- g. Exhibits pride in the trade
- h. Controls temper at all times
- i. Is punctual
- j. Is a good citizen

6. a. Mathematical ability
   b. Color perception
   c. Manipulative skills with small components
   d. Troubleshooting
7. Evaluated to satisfaction of instructor
8. Evaluated to satisfaction of instructor
9. Evaluated to satisfaction of instructor
10. Evaluated to satisfaction of instructor
11. Evaluated to satisfaction of instructor

SAFETY
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to distinguish between applications of the federal safety code colors and state general shop safety rules. The student should also be able to match classes of fires to their correct definitions and be able to match types of fire extinguishers to their correct uses. This knowledge will be shown by completing assignment sheets and unit test with a minimum score of 100 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with safety to their correct definitions.
2. List the colors of the federal safety code.
3. Distinguish among federal safety code color indications.
4. State personal safety rules.
5. State general shop safety rules.
6. State electrical safety rules.
7. State safety rules to follow when using electrical tools.
8. Name major causes of electrical accidents.
9. Label parts of the fire triangle.
10. Match classes of fires to their correct definitions.
11. Match types of fire extinguishers to their correct uses.
12. State safety practices for job-built, extension, and A-frame ladders.
13. Arrange in order steps to follow in case of an accident.
14. List in order rescue procedures used in electrical accidents.
15. Label the color coding of safety tags and signs.
16. Complete a general shop safety quiz.
17. Complete a safety practice form.
18. Check general color vision.

SAFETY
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Provide students with objective sheet.

  B. Provide students with information and assignment sheets.

  C. Make transparencies.

  D. Discuss unit and specific objectives.

  E. Discuss information and assignment sheets.

  F. Invite a fire fighter to talk about various types of fires and to demonstrate the proper use of a fire extinguisher, emphasizing putting out electrical fires.

  G. Obtain safety signs and display in shop area.

  H. Give test.

II. Instructional materials

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM #1–Lockout Device

    2. TM #2--The Fire Triangle

    3. TM #3--Types of Fire Extinguishers

    4. TM #4–Ladder Safety Practices

    5. TM #5--Safe Ladder Angle

    6. TM #6--Rescue Procedure in Electrical Accidents

  D. Assignment sheets

    1. Assignment Sheet #1--Complete a General Shop Safety Quiz

    2. Assignment Sheet #2--Complete a Safety Practice Form

    3. Assignment Sheet #3--Check General Color Vision

SUGGESTED ACTIVITIES

E. Answers to assignment sheets

F. Test

G. Answers to test

III. Unit references

A. Bureau of Naval Personel. *Basic Electricity: Rate Training Manual, Navpers 10086-B*. Washington, D.C.: U.S. Government Printing Office, 1969.

B. Wantiez, Gary W. *Air Conditioning and Refrigeration, Book One*. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1977.

SAFETY
UNIT II

INFORMATION SHEET

I. Terms and definitions

   A. Accident-Any suddenly occurring, unintentional event which causes injury or property damage

   B. First aid–Immediate, temporary care given to a victim of an accident or sudden illness until a physician can arrive

   C. Safety--State or condition of being safe; freedom from danger, risk, or injury

   D. Tag--Safety sign that can be attached to a particular piece of equipment

II. Federal safety code colors

   A. Federal safety red

   B. Federal safety yellow

   C. Federal safety orange

   D. Federal safety purple

   E. Federal safety green

   F. Federal safety black

   G. Federal safety white

III. What federal safety code colors indicate

   A. Federal safety red

      1. Location of fire-fighting equipment

      2. Portable containers of flammable liquid

      3. Emergency stop bars, stop buttons, and emergency electrical stop switches on machinery

   B. Federal safety yellow

      1. Caution, and marking of physical hazards

      2. Waste containers for explosive or combustible material

      3. Caution against starting, using, or moving equipment under repair

      4. Starting point of machinery

INFORMATION SHEET

C. Federal safety orange

  1. Dangerous parts of machines
  2. Safety starter buttons, and parts of equipment that may cause electrical shock
  3. Exposed parts (edges only) of pulleys, gears, rollers, cutting devices, and power jaws

D. Federal safety purple--Radiation hazard

E. Federal safety green

  1. Safety
  2. Location of first-aid equipment

     (NOTE: This applies to equipment other than fire-fighting equipment.)

F. Federal safety black

  1. Traffic flow
  2. Housekeeping purposes

     EXAMPLE: Custodian's closet

G. Federal safety white

  1. Traffic flow
  2. Housekeeping purposes

     (NOTE: Black and white may be used together or by themselves.)

IV. Personal safety rules

  A. Wear clothing appropriate for activity
  B. Secure long hair before operating rotating equipment
  C. Wear safety goggles any time there is possibility of eye injury
  D. Do not wear loose clothing when operating or working around rotating machinery
  E. Remove all jewelry when working in shop

INFORMATION SHEET

V. General shop safety rules

A. Keep all tools clean, sharp, and in safe working order

B. Report to instructor or supervisor any defect in tools, machines, or other equipment

C. Leave all safety devices on equipment, except with the *specific authorization* of instructor or supervisor

D. Operate machinery or test equipment only after proper instruction

E. Report ALL accidents to instructor or supervisor

F. Turn power off when leaving a machine or tool

G. Disconnect power from machine or tool when performing maintenance

H. Keep shop floor clear of scraps, litter, or debris

I. Clean up immediately any spilled liquid

J. Store oily shop towels or oily waste in *metal* containers

K. Always wear safety goggles when grinding, buffing, hammering, or cleaning with compressed air

L. Do not work in shop without instructor or supervisor present

M. Consider safety of others when working in shop

N. Report any condition which may lead to an accident

O. Conduct yourself in a safe manner at all times

P. Use proper tools and equipment for the job

Q. Operate machines and equipment only when permitted by instructor or supervisor

R. Make sure everyone is clear of work area when using compressed air to clean

S. Check all equipment before turning it on

T. Use plenty of light; do not work in improperly lit area

U. Make sure all revolving machine parts are well-guarded

V. Give prompt attention to injuries

INFORMATION SHEET

VI. Electrical safety rules

- A. *Never* underestimate the danger of electricity
- B. Remember that involuntary shock can cause personal injury and injury to others
- C. Always turn off power to equipment, unless power is necessary for testing
- D. *Never* experiment by touching circuits to see if voltage is present
- E. Remove all jewelry before working on equipment
- F. *Never* work on electrical equipment while wet
- G. Check for the presence of high voltage
- H. Always have safety observer present when working on live equipment
- I. Work only on equipment with which you are familiar
- J. *Never* take safety devices for granted

  EXAMPLES: Fuses, circuit breakers, protective interlocks
- K. Tag or lock all electrical power switches when working on equipment (Transparency #1)

VII. Safety rules to follow when using electrical tools

- A. Ground all power tools
- B. Use proper sized electrical cord
- C. Keep safety guards on all tools
- D. Do not use tools with frayed or damaged cords
- E. Stand on dry, nonconductive surfaces when using tools
- F. Wear eye protection

VIII. Major causes of electrical accidents

- A. Carelessness
- B. Misuse of equipment

IX. Parts of the fire triangle (Transparency #2)

- A. Fuel

  (NOTE: Fuel is any combustible material.)

INFORMATION SHEET

B. Heat

(NOTE: There has to be enough heat to raise the fuel to the ignition point.)

C. Oxygen

(NOTE: Oxygen is necessary to sustain combustion.)

X. Classes of fires

A. **Class A**--Fires that occur in ordinary combustible materials

EXAMPLES: Wood, rags, trash

B. **Class B**--Fires that occur with flammable liquid

EXAMPLES: Gasoline, oil, grease, paint thinners

C. **Class C**--Fires that occur in or near electrical equipment

EXAMPLES: Motors, switchboards, electrical wiring

D. **Class D**--Fires that occur with combustible metals

EXAMPLE: Magnesium

XI. Types of fire extinguishers and their uses (Transparency #3)

A. Pressurized water--Used on **Class A** fires

(NOTE: Operate pressurized water fire extinguishers by squeezing a handle or trigger.)

B. Soda-Acid--Used on **Class A** fires

(NOTE: Operate soda-acid fire extinguishers by turning extinguisher upside down.)

C. Carbon dioxide--Used on **Class B** and **C** fires

(NOTE: Operate carbon dioxide extinguishers by squeezing handle or trigger.)

D. Dry chemical--Used on **Class B, C,** and **D** fires

(NOTE: Operate dry chemical extinguishers by squeezing a handle, lever, or trigger. Dry sand works as effectively as any dry chemical. There are other more highly refined dry chemical fire extinguishers, but their cost places them out of reach of most shops.)

E. Foam--Used on **Class A** and **B** fires

(NOTE: Operate foam extinguishers by turning extinguisher upside down.)

INFORMATION SHEET

XII. Safety practices for job-built, extension, and A-frame ladders (Transparency #4)

A. Make sure ladder is tall enough

B. Maintain safe ladder angle (Transparency #5)

C. Secure top of job-built and extension ladders when possible

D. Use nonskid feet or secure bottom of ladder

E. Do not paint ladder

F. Do not stand on top of any ladder

G. Do not straddle A-frame ladders

XIII. Steps to be followed in case of an accident

A. Report any accidents or injuries to instructor or supervisor, no matter how minor they may seem

(NOTE: An accident report will be filled out by instructor or supervisor, and an investigation will take place to determine cause and prevention of future accidents.)

B. Administer first aid, if needed

C. Telephone for professional medical help, if needed

XIV. Rescue procedures used in electrical accidents (Transparency #6)

A. Locate circuit breaker and turn off, if possible

(CAUTION: If conductor is to be moved, use dry, wooden broom stick or some other nonconductive device. If individual is to be moved, use several thicknesses of paper or cloth as an insulator. DO NOT grab person with bare hand. If it is high voltage [over 600V] contact proper authorities.)

B. Separate victim from conductor

(NOTE: Decide if it would be easier to move person or conductor.)

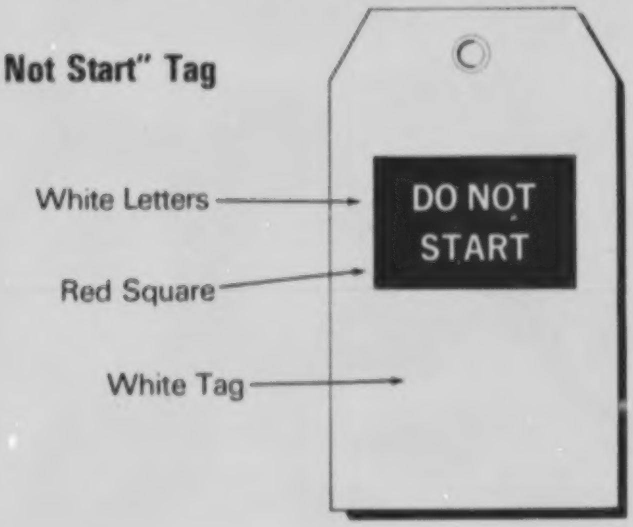
C. Follow "Steps to be followed in case of an accident"

INFORMATION SHEET

XV. Color coding of safety tags and signs

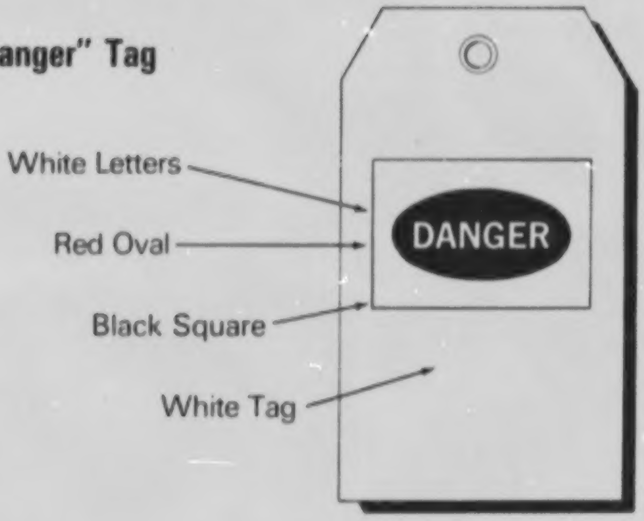
A. "Do Not Start" tag or sign

"Do Not Start" Tag


White Letters
DO NOT
START
Red Square
White Tag

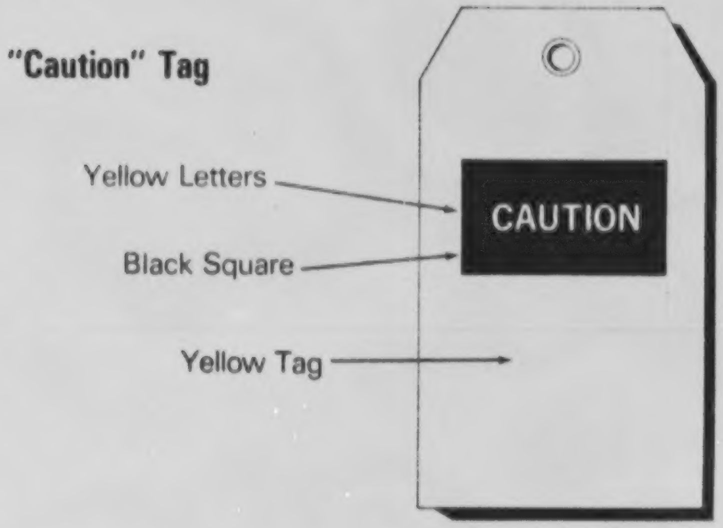
B. "Danger" tag or sign

"Danger" Tag

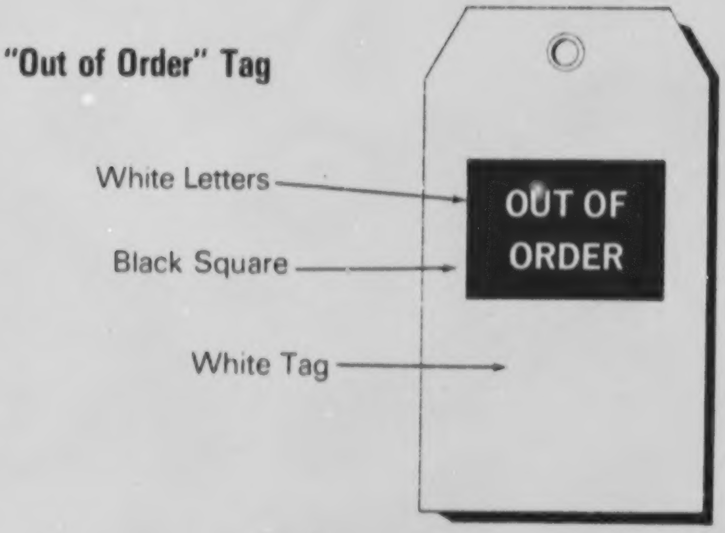

White Letters
DANGER
Red Oval
Black Square
White Tag

INFORMATION SHEET

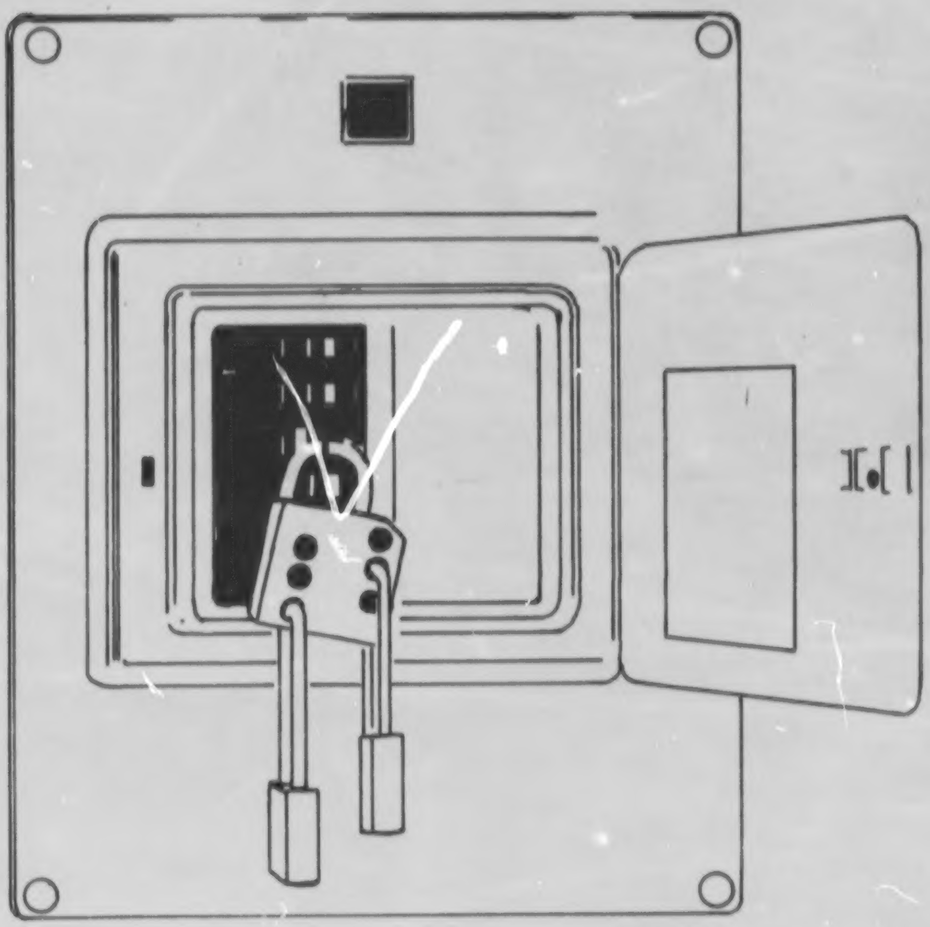
C. "Caution" tag or sign


"Caution" Tag
Yellow Letters
Black Square
Yellow Tag
CAUTION

D. "Out of Order" tag or sign

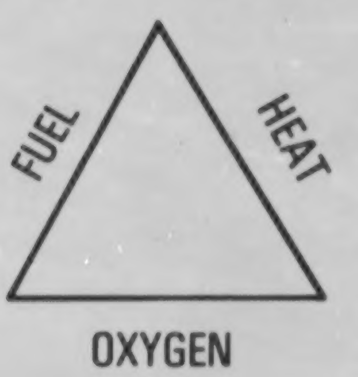

"Out of Order" Tag
White Letters
Black Square
White Tag
OUT OF ORDER

Lockout Device

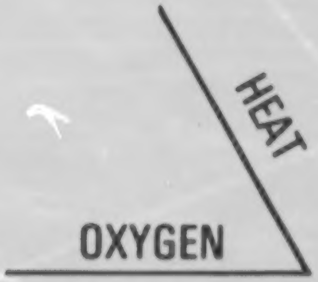


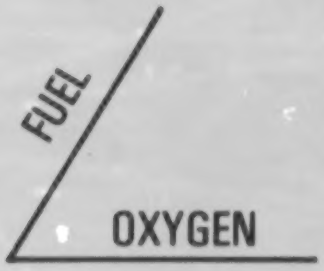
The Fire Triangle

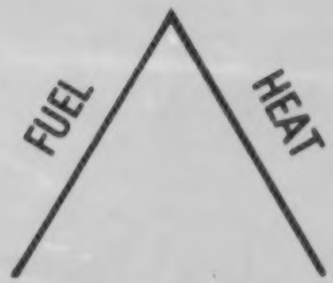
To produce fire, three things must be present at the same time.


FUEL
HEAT
OXYGEN

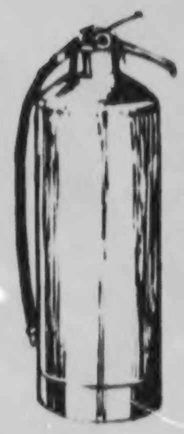
If any one of the three is missing, a fire cannot be started or, with the removal of any one, the fire will be extinguished.


HEAT
OXYGEN

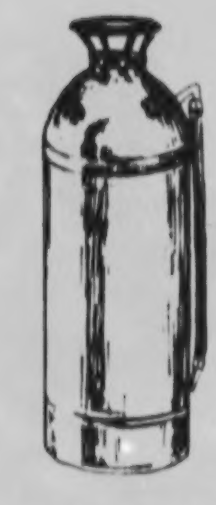

FUEL
OXYGEN



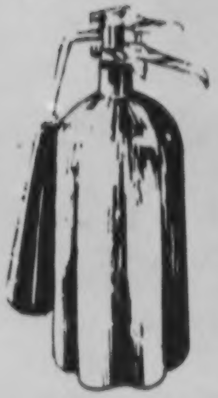
Types of Fire Extinguishers



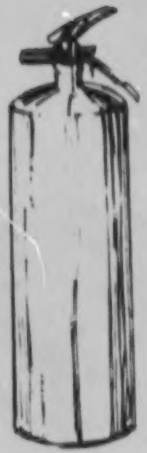
Pressurized Water



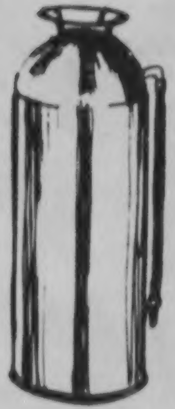
Soda-Acid



Carbon Dioxide



Dry Chemical



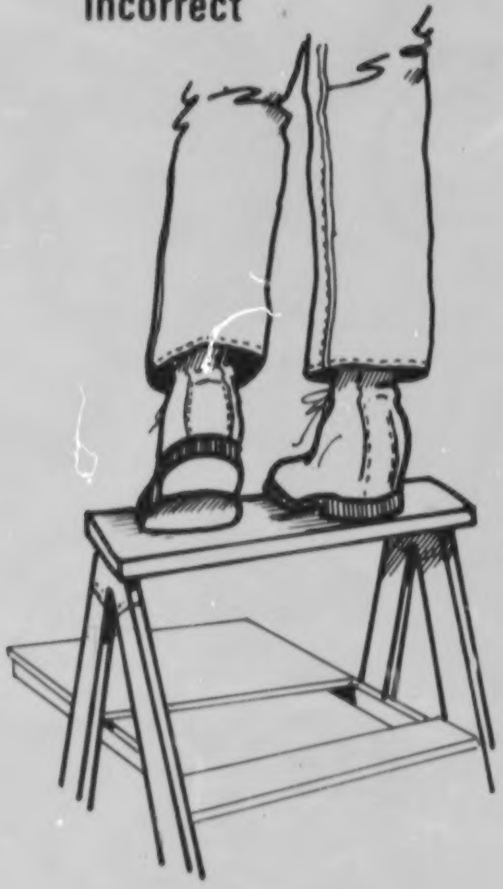
Foam

TM #3

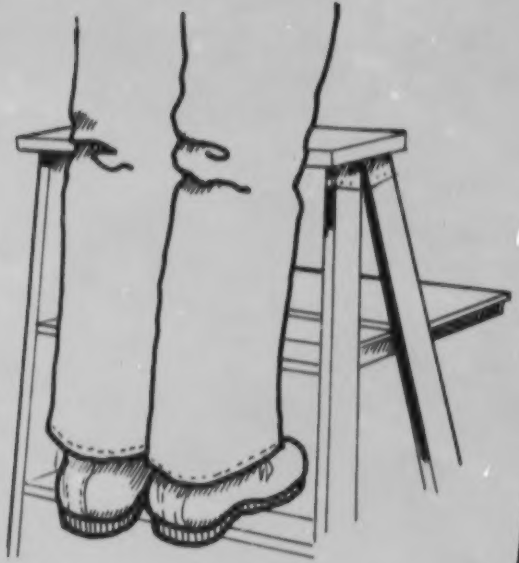
IIEE - 55-A

Ladder Safety Practices

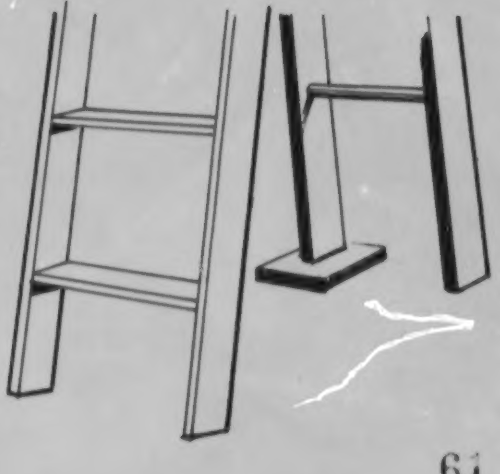
Incorrect



Correct



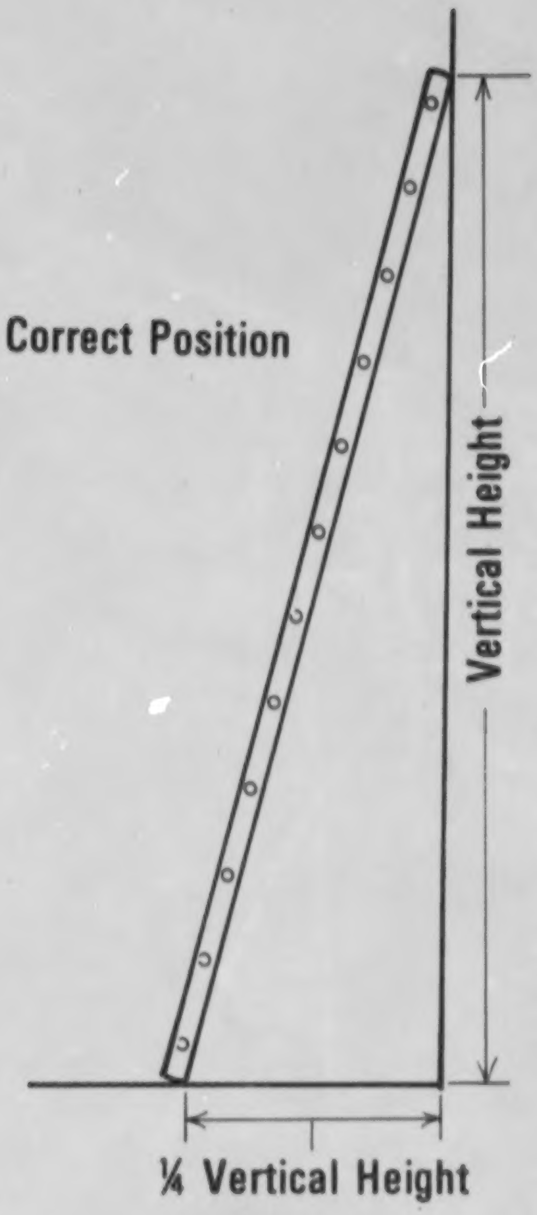
Use Block to Level Ladder When Necessary



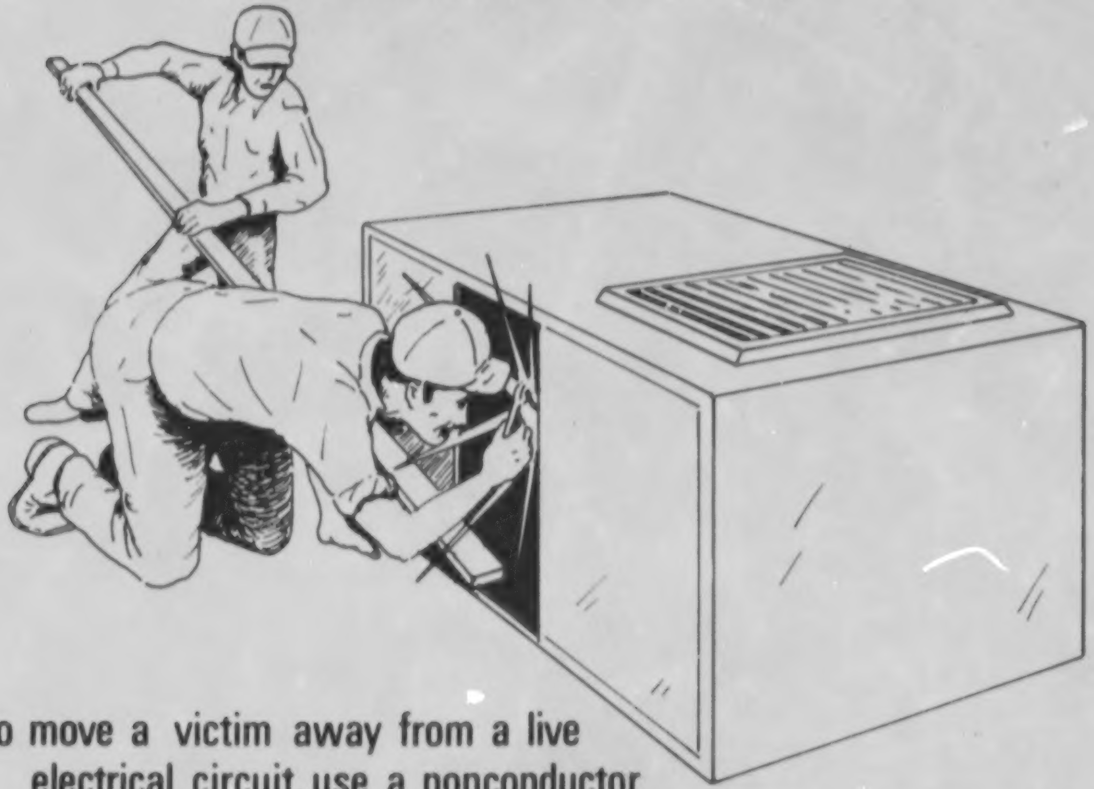
TM #4

IIEE-57-A

Safe Ladder Angle


Correct Position
Vertical Height
¼ Vertical Height

Rescue Procedure In Electrical Accidents



To move a victim away from a live electrical circuit, use a nonconductor such as a long dry wooden or plastic pole or a very dry tree branch or a rope

SAFETY
UNIT II

ASSIGNMENT SHEET #1–GENERAL SHOP SAFETY QUIZ

NAME ______________________________ SCORE ______________

Complete the safety quiz below by circling "T" if the statement is true and "F" if the statement is false.

T F STATEMENT

T F 1. Report all injuries to instructor or supervisor

T F 2. All fire-fighting equipment is designated by the color red

T F 3. Have instructor explain operating procedures for only that equipment and machinery with which you are not familiar

T F 4. Leave safety devices off some small machines

T F 5. Use only tools and equipment in good condition

T F 6. Learn CPR for emergency procedures in case of heart or breathing stoppage

T F 7. An acceptable fire extinguisher for Class C fires is the carbon dioxide extinguisher

T F 8. Sit on the top rung of an A-frame ladder as a safety procedure

T F 9. Observe all warning signs and tags

T F 10. Use equipment only after its correct operating procedures have been taught

T F 11. Do not wear worn or ragged clothing when working on or near machinery

T F 12. Dim lights when working to conserve energy

T F 13. Always have safety observer present when working on live equipment

T F 14. First-aid stations are marked with a red cross

T F 15. "Horseplay" should never occur in the shop

T F 16. Always use the proper tool for the job

T F 17. Paint wooden ladders to add strength and make them more visible

ASSIGNMENT SHEET #1

T F STATEMENT

T F 18. Electrical fires are classified as **Class C** fires

T F 19. Remove all jewelry, metal-framed glasses, and other metal objects when working in an electrical shop

T F 20. Wear safety goggles when there is a chance of getting foreign material in the eyes

T F 21. Always rely upon or take for granted safety devices

T F 22. Waste containers for explosive or combustible materials are yellow plastic

T F 23. Tag or lock all electrical power switches when working on equipment

T F 24. Do not use worn or frayed cords when using tools

T F 25. Electrical fires may often be controlled by turning off power

T F 26. The two major causes of electrical accidents are carelessness and misuse of equipment

T F 27. An accident is any suddenly occurring, unintentional event which causes injury or property damage

T F 28. Report defective tools and equipment to the instructor or supervisor

T F 29. Leave machine running while not in use

T F 30. The three parts of the fire triangle are fuel, heat, and oxygen

SAFETY
UNIT II

ASSIGNMENT SHEET #2--SAFETY PRACTICE FORM

NAME ______________________________ SCORE ____________

Complete this safety practice form and return to instructor for filing.

______________________________ SCHOOL

______________________________, who is enrolled in a vocational ______________ course, will, as a part of the shop experience, operate machines and equipment, providing that the parent or guardian gives written permission.

It is understood that each student will be given proper instruction, both in the use of the equipment and in correct safety procedures concerning it, before being allowed to operate it.

The student must assume responsibility for the following safe practices, and we, therefore, ask that the student subscribe to the following safety pledge.

1. I promise to follow all safety rules for the shop.
2. I promise never to use a machine or equipment without first having permission from the teacher.
3. I will not use a particular machine or a piece of equipment unless I have been instructed in its use and have scored 100% on the safety test.
4. I will report any accident or injury to the teacher immediately.

Date ____________ Student's Signature ______________________________

I hereby give my consent to allow my son or daughter to operate all machines and equipment necessary to carry out the requirements of the course in which he/she is enrolled.

Date ____________ Parent or Guardian's Signature ______________________________

Parents or guardians are cordially invited to visit the shops to inspect the machines and to see them in operation at any time.

(NOTE: Parental consent is necessary only if the student is a minor.)

SAFETY
UNIT II

ASSIGNMENT SHEET #3--CHECK GENERAL COLOR VISION

NAME ____ SCORE ________________

In the electricity-electronics field, many items are color-coded. Examples of these are resistors, diodes, capacitors, wiring, and transformer leads. For this reason a technician must have good color vision. The instructor will designate specific resistors and the colors should be recorded in the spaces provided.

(NOTE: If some resistors do not have five color bands leave those spaces blank. If the instructor prefers, some other means of providing colors for the test may be used.)

#1 __________ __________ __________ __________ __________

#2 __________ __________ __________ __________ __________

#3 __________ __________ __________ __________ __________

#4 __________ __________ __________ __________ __________

#5 __________ __________ __________ __________ __________

#6 __________ __________ __________ __________ __________

#7 __________ __________ __________ __________ __________

SAFETY
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. T
2. T
3. F
4. F
5. T
6. T
7. T
8. F
9. T
10. T
11. T
12. F
13. T
14. F
15. T
16. T
17. F
18. T
19. T
20. T
21. F
22. F
23. T
24. T
25. T
26. T
27. T
28. T
29. F
30. T

Assignment Sheet #2--Evaluated to satisfaction of instructor

Assignment Sheet #3--Evaluated to satisfaction of instructor

SAFETY
UNIT II

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with safety to their correct definitions. Write the correct numbers in the blanks.

_____a. State or condition of being safe; freedom from danger, risk, or injury	1. Tag
_____b. Immediate, temporary care given to a victim of an accident or sudden illness until a physician can arrive	2. Accident
_____c. Any suddenly occurring, unintentional event which causes injury or property damage	3. Safety
_____d. Safety sign that can be attached to a particular piece of equipment	4. First aid

2. List the colors of the federal safety code.

a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

f. ______________________

g. ______________________

3. Distinguish among federal safety code color indications. Write a "Y" in the blanks before yellow, a "G" for green, an "R" for red, a "W" for white, a "B" for black, an "O" for orange, and a "P" for purple. An answer may be used more than once, and a blank may have more than one correct answer.

_____a. Location of fire-fighting equipment

_____b. Waste containers for explosive or combustible material

_____c. Dangerous parts of machines

_____d. Traffic flow

_____e. Safety

_____f. Radiation hazard

TEST

_____g. Housekeeping purposes

_____h. Location of first-aid equipment

_____i. Portable containers of flammable liquid

_____j. Caution, and marking of physical hazards

_____k. Exposed parts (edges only) of pulleys, gears, rollers, cutting devices, and power jaws

_____l. Emergency stop bars, stop buttons, and emergency electrical stop switches on machinery

_____m. Starting point of machinery

_____n. Safety starter buttons, and parts of equipment that may cause electrical shock

_____o. Caution against starting, using, or moving equipment under repair

4. State personal safety rules.

a. ____

____

b. ____

____

c. ____

____

d. ____

____

e. ____

____

5. State ten general shop safety rules.

a. ____

____

b. ____

____

TEST

c. ____________________

____

d. ____________________

____

e. ____________________

____

f. ____________________

____

g. ____________________

____

h. ____________________

____

i. ____________________

____

j. ____________________

____

6. State five electrical safety rules.

a. ____________________

____

b. ____________________

____

c. ____________________

____

d. ____________________

____

e. ____________________

____

TEST

7. State four safety rules to follow when using electrical tools.

a. ____

____

b. ____

____

c. ____

____

d. ____

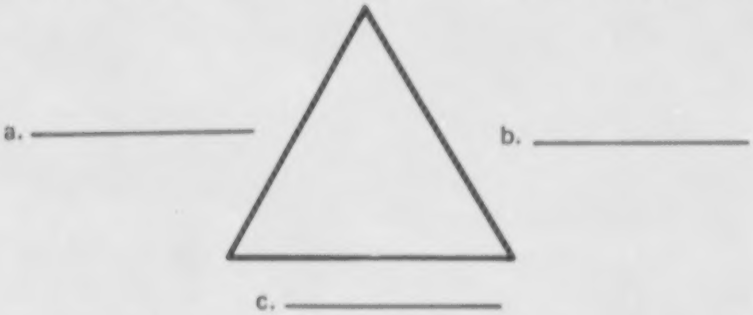
____

8. Name major causes of electrical accidents.

a. ____

b. ____

9. Label parts of the fire triangle. Write your answers in the blanks provided.



10. Match classes of fires to their correct definitions. Write the correct numbers in the blanks.

_____a. Fires that occur with flammable liquid

_____b. Fires that occur in ordinary combustible materials

_____c. Fires that occur in or near electrical equipment

_____d. Fires that occur with combustible metals

1. Class A
2. Class B
3. Class C
4. Class D

TEST

11. Match types of fire extinguishers to their correct uses. Write the correct numbers in the blanks. An answer may be used more than once, and a blank may have more than one correct answer.

_____a. Class C

_____b. Class B

_____c. Class A

_____d. Class D

1. Pressurized water
2. Foam
3. Soda-acid
4. Carbon dioxide
5. Dry chemical

12. State four safety practices for job-built, extension, and A-frame ladders.

a. ____

b. ____

c. ____

d. ____

13. Arrange in order steps to be followed in case of an accident. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. Administer first aid, if needed

_____b. Report any accidents or injuries to instructor or supervisor, no matter how minor they may seem

_____c. Telephone for professional medical help, if needed

14. List in order rescue procedures used in electrical accidents.

a. ____

____

b. ____

____

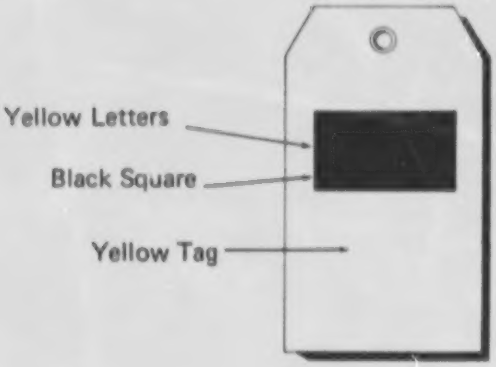
c. ____

____

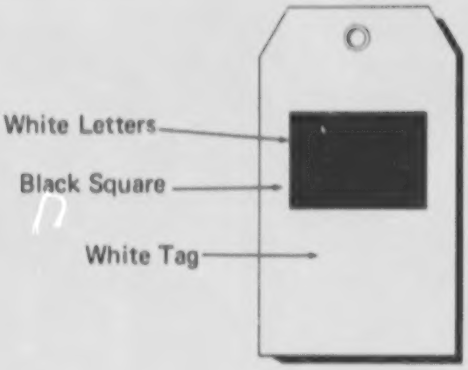
TEST

15. Label the color coding of safety tags and signs shown below. Write your answers in the blanks.

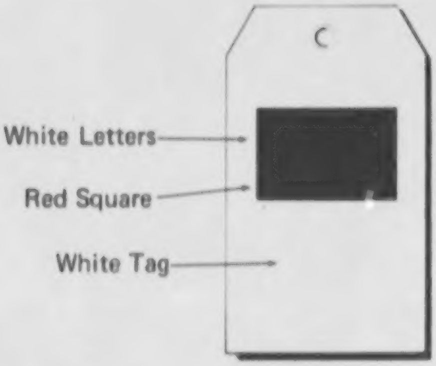
a. ______________________________


Yellow Letters
Black Square
Yellow Tag

b. ______________________________

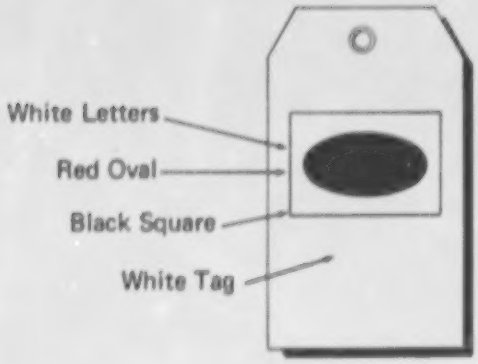

White Letters
Black Square
White Tag

c. ______________________________


White Letters
Red Square
White Tag

TEST

d. ________________________________


White Letters
Red Oval
Black Square
White Tag

(NOTE: Test questions 16-18 are assignment sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

16. Complete a general shop safety quiz.

17. Complete a safety practice form.

18. Check general color vision.

SAFETY
UNIT II

ANSWERS TO TEST

1. a. 3
   b. 4
   c. 2
   d. 1
2. a. Federal safety red
   b. Federal safety yellow
   c. Federal safety orange
   d. Federal safety purple
   e. Federal safety green
   f. Federal safety black
   g. Federal safety white
3. a. R
   b. Y
   c. O
   d. B, W
   e. G
   f. P
   g. B, W
   h. G
   i. R
   j. Y
   k. O
   l. R
   m. Y
   n. O
   o. Y
4. a. Wear clothing appropriate for activity
   b. Secure long hair before operating rotating equipment
   c. Wear safety goggles any time there is possibility of eye injury
   d. Do not wear loose clothing when operating or working around rotating machinery
   e. Remove all jewelry when working in shop

ANSWERS TO TEST

5. Answers should include any ten of the following

   a. Keep all tools clean, sharp, and in safe working order

   b. Report to instructor or supervisor any defect in tools, machines, or other equipment

   c. Leave all safety devices on equipment, except with *specific authorization* of instructor or supervisor

   d. Operate machinery or test equipment only after proper instruction

   e. Report ALL accidents to instructor or supervisor

   f. Turn power off when leaving a machine or tool

   g. Disconnect power from machine or tool when performing maintenance

   h. Keep shop floor clear of scraps, litter, or debris

   i. Clean up immediately any spilled liquid

   j. Store oily shop towels or oily waste in *metal* containers

   k. Always wear safety goggles when grinding, buffing, hammering, or cleaning with compressed air

   l. Do not work in shop without instructor or supervisor present

   m. Consider safety of others when working in shop

   n. Report any condition which may lead to an accident

   o. Conduct yourself in a safe manner at all times

   p. Use proper tools and equipment for the job

   q. Operate machines and equipment only when permitted by instructor or supervisor

   r. Make sure everyone is clear of work area when using compressed air to clean

   s. Check all equipment before turning it on

   t. Use plenty of light; do not work in improperly lit area

   u. Be sure all revolving machine parts are well-guarded

   v. Give prompt attention to injuries

ANSWERS TO TEST

6. Answers should include any five of the following
   - a. *Never* underestimate the danger of electricity
   - b. Remember that involuntary shock can cause personal injury and injury to others
   - c. Always turn off power to equipment, unless power is necessary for testing
   - d. *Never* experiment by touching circuits to see if voltage is present
   - e. Remove all jewelry before working on equipment
   - f. *Never* work on electrical equipment while wet
   - g. Check for presence of high voltage
   - h. Always have safety observer present when working on live equipment
   - i. Work only with equipment with which you are familiar
   - j. *Never* take safety devices for granted
   - k. Tag or lock all electrical power switches when working on equipment
7. Answers should include any four of the following
   - a. Ground all power tools
   - b. Use proper sized electrical cord
   - c. Keep safety guards on all tools
   - d. Do not use tools with frayed or damaged cords
   - e. Stand on dry, nonconductive surfaces when using tools
   - f. Wear eye protection
8. a. Carelessness
   - b. Misuse of equipment
9. a. Fuel
   - b. Heat
   - c. Oxygen
10. a. 2
    - b. 1
    - c. 3
    - d. 4

ANSWERS TO TEST

11. a. 4, 5
    b. 2, 4, 5
    c. 1, 2, 3
    d. 5
12. Answer should include any four of the following
    a. Make sure ladder is tall enough
    b. Maintain safe ladder angle
    c. Secure top of job-built and extension ladders when possible
    d. Use nonskid feet or secure bottom of ladder
    e. Do not paint ladder
    f. Do not stand on top of any ladder
    g. Do not straddle A-frame ladders
13. a. 2
    b. 1
    c. 3
14. a. Locate circuit breaker and turn off, if possible
    b. Separate victim from conductor
    c. Follow "Steps to be followed in case of an accident"
15. a. Caution
    b. Out of Order
    c. Do Not Start
    d. Danger
16. Evaluated to satisfaction of instructor
17. Evaluated to satisfaction of instructor
18. Evaluated to satisfaction of instructor

HAND TOOLS
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to identify, use, and care for common and specialized tools used in the industrial electricity/electronics program. This knowledge will be shown by completing job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with hand tools to their correct definitions.
2. Label common hand tools used in industrial electricity/electronics.
3. Label electronics/electricity-specific hand tools used in industrial maintenance.
4. Match common hand tools to their correct uses.
5. Match electricity/electronics-specific hand tools to their correct uses.
6. List factors to consider when purchasing hand tools.
7. List rules for care of various hand tools.
8. Demonstrate the ability to
   a. Clean and lubricate an adjustable hand tool.
   b. Grind a flat-blade screwdriver.
   c. Use a cutting-crimping tool.
   d. Adjust wire strippers.
   e. Set up and use a hacksaw.
   f. Cut rigid conduit with a pipe cutter.
   g. Ream rigid conduit.
   h. Bend EMT conduit.
   i. Use a knockout punch.
   j. Use a hole saw.

HAND TOOLS
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in the job sheets.

   G. Demonstrate the use of the various tools as they are discussed.

   H. Show and explain an industrial blueprint.

   I. Give test.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency masters

      1. TM #1--Using an Adjustable Wrench

      2. TM #2--Using a Circuit Tester

   E. Job sheets

      1. Job Sheet #1--Clean and Lubricate an Adjustable Hand Tool

      2. Job Sheet #2--Grind a Flat-Blade Screwdriver

      3. Job Sheet #3--Use a Cutting/Crimping Tool

      4. Job Sheet #4--Adjust Wire Strippers

      5. Job Sheet #5--Set Up and Use a Hacksaw

      6. Job Sheet #6--Cut Rigid Conduit with a Pipe Cutter

      7. Job Sheet #7--Ream Rigid Conduit

SUGGESTED ACTIVITIES

8. Job Sheet #8--Bend EMT Conduit
9. Job Sheet #9--Use a Knockout Punch
10. Job Sheet #10--Use a Hole Saw

F. Test

G. Answers to test

III. Unit reference--Graf, Rudolf F. ed. *Dictionary of Electronics.* Radio Shack, 1975-76.

HAND TOOLS
UNIT III

INFORMATION SHEET

I. Terms and definitions

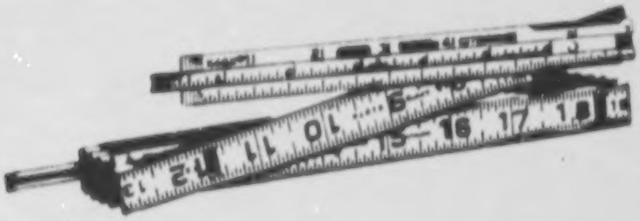
- A. Print--Industrial blueprint; industrial wiring diagram
- B. Coupling--Mechanical device for connecting conduit and cabling
- C. Conduit--Pipe or tube which holds and protects wires or cables
- D. Plasterboard--Thin board formed of layers of plaster and paper; sheet-rock
- E. Circuit box--Box where electrical connections are made, usually through circuit breakers
- F. Insulation--Nonconductive material that prevents leakage of electricity from a conductor and protects against accidental contact
- G. Wire lug--Metal connector crimped or soldered to a conductor; allows conductor to be fastened with a screw or bolt
- H. Snap ring--Metal ring which fastens around or in a shaft to keep other parts stationary
- I. Fuse--Safety device placed in a circuit; in cases of excessive current, it melts, thus opening the circuit
- J. Heat shrink--Nonconductive material placed around a conductor for insulation; shrinks when heated
- K. Spaghetti--Nonconductive material placed around a conductor for insulation; does not shrink
- L. Cable-tie--Plastic straps with pull-through fasteners for binding together conductors or cables
- M. Conductor--Material through which electrons flow easily; used to connect components
- N. Live circuit--Circuit with voltage applied and flowing current
- O. Arbor--Shaft or spindle used to hold a revolving cutting tool or the work to be cut
- P. Chuck--Device for holding a component of a tool rigid

INFORMATION SHEET

II. Common hand tools used in industrial electricity/electronics (Figures 1-24)

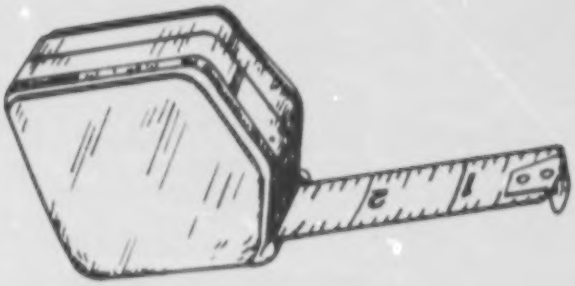
A. Folding rule

FIGURE 1



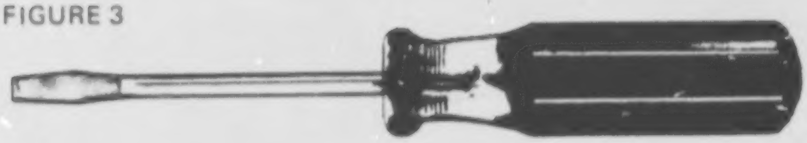
B. Tape measure

FIGURE 2



C. Flat-blade screwdriver

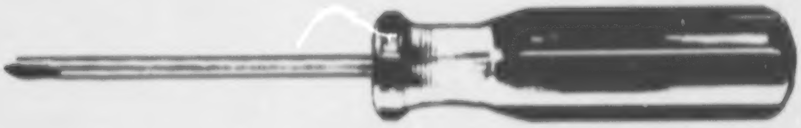
FIGURE 3



INFORMATION SHEET

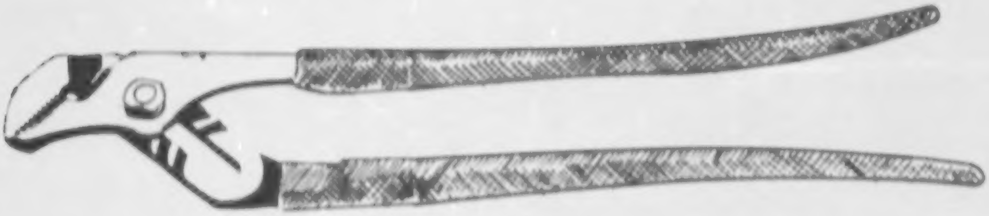
D. Phillips screwdriver

FIGURE 4



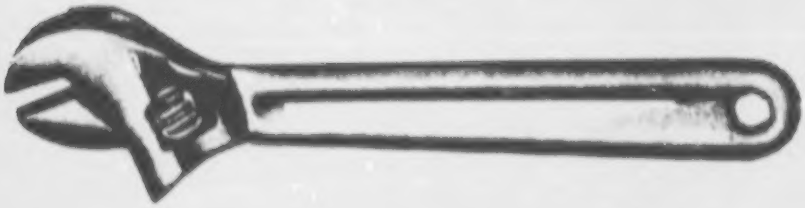
E. Pump pliers

FIGURE 5



F. Adjustable wrench

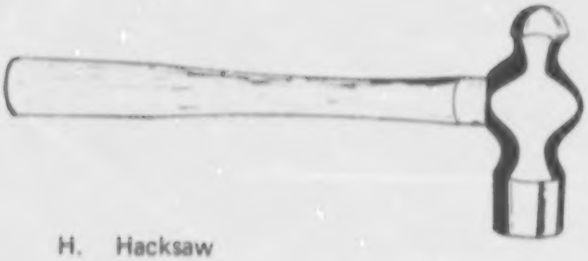
FIGURE 6



INFORMATION SHEET

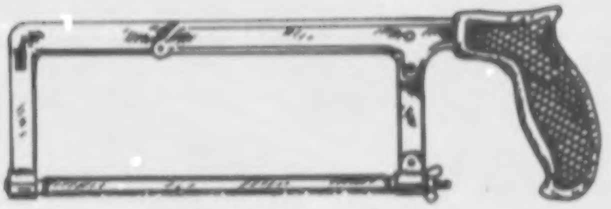
G. Ball peen hammer

FIGURE 7



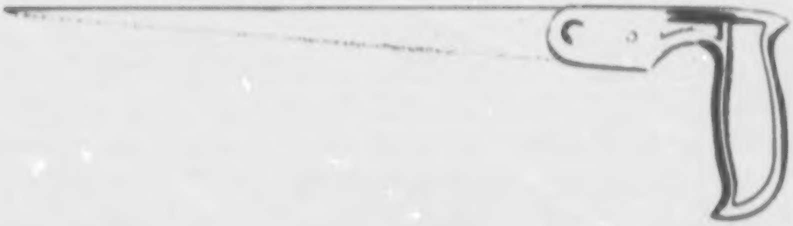
H. Hacksaw

FIGURE 8



I. Keyhole saw

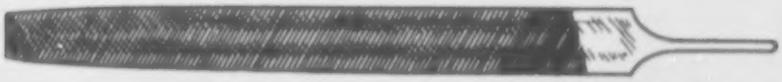
FIGURE 9



INFORMATION SHEET

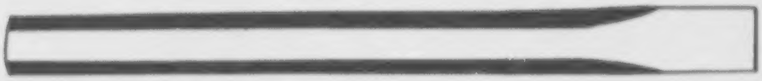
J. File

FIGURE 10



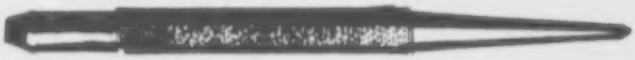
K. Chisel

FIGURE 11



L. Center punch

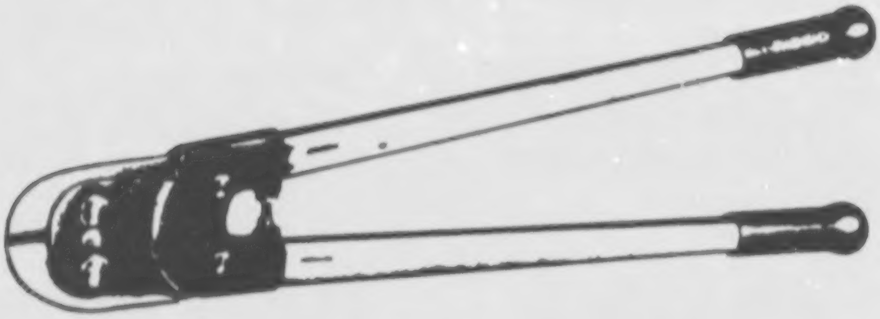
FIGURE 12



INFORMATION SHEET

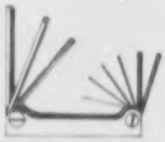
M. Bolt cutter

FIGURE 13



N. Hex key set (Allen wrenches)

FIGURE 14



O. Torpedo level

FIGURE 15

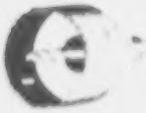
INFORMATION SHEET

P. Knockout punch

FIGURE 16

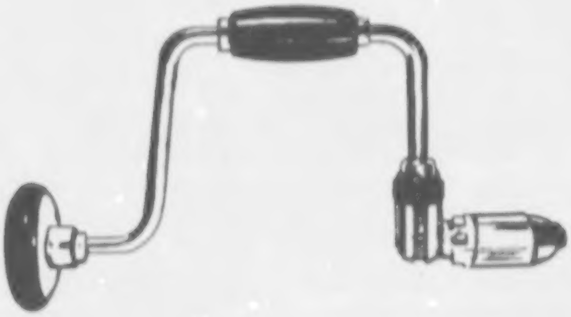
Q. Hole saw and arbor

FIGURE 17



R. Drill brace

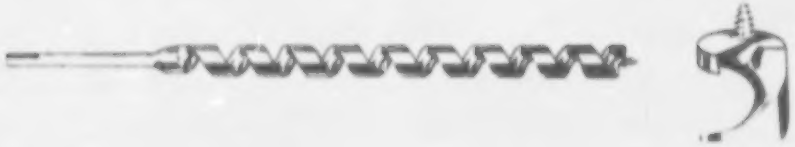
FIGURE 18



INFORMATION SHEET

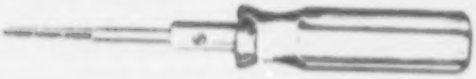
S. Ship auger drill bit

FIGURE 19



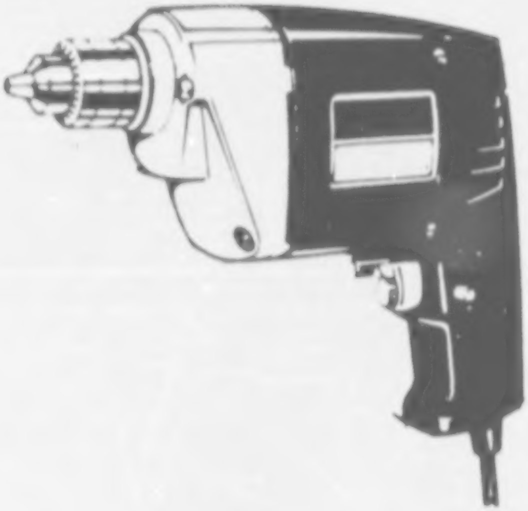
T. Tap tool

FIGURE 20



U. Drill motor

FIGURE 21



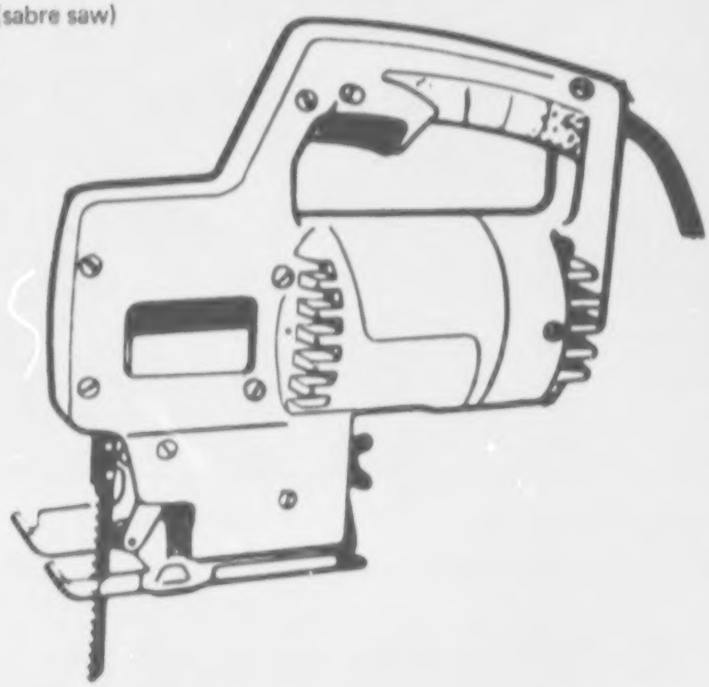
INFORMATION SHEET

V. Drill bit

FIGURE 22

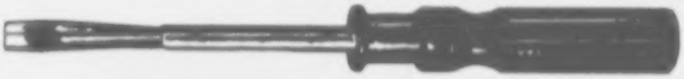
W. Jigsaw (sabre saw)

FIGURE 23



X. Screw-holding screwdriver

FIGURE 24

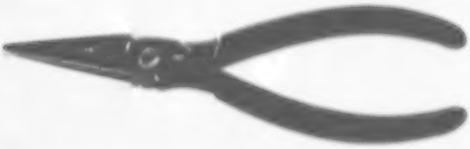


INFORMATION SHEET

III. Electricity/electronics-specific hand tools used in industrial maintenance (Figures 25-49)

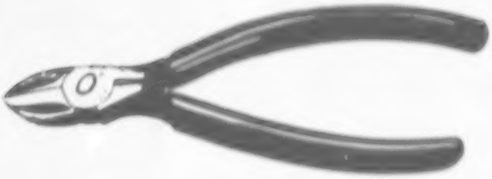
A. Needle-nose pliers

FIGURE 25



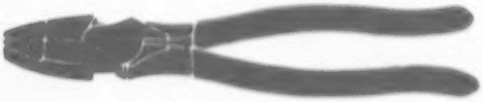
B. Diagonal pliers (dykes)

FIGURE 26



C. Lineman's pliers

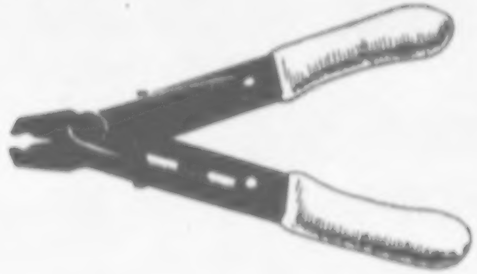
FIGURE 27



INFORMATION SHEET

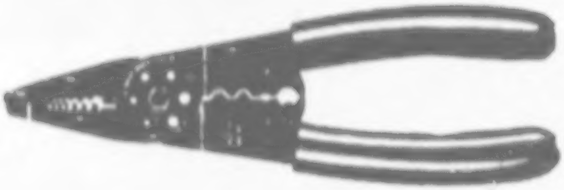
D. Adjustable wire stripper

FIGURE 28



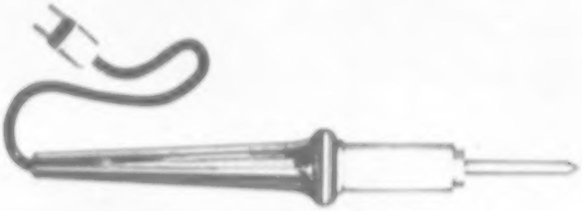
E. Cutting/crimping tool

FIGURE 29



F. Soldering iron (approximately 25 W)

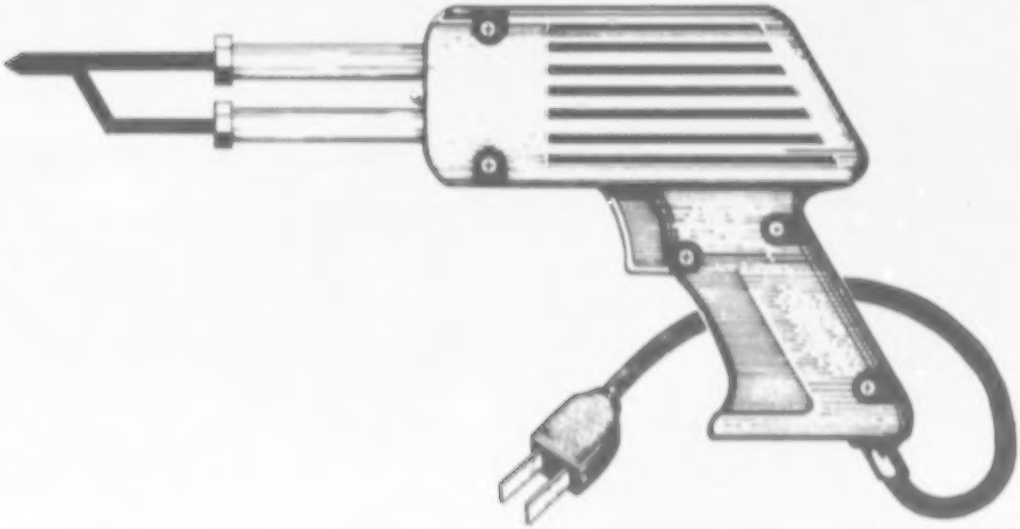
FIGURE 30



INFORMATION SHEET

G. Soldering gun

FIGURE 31

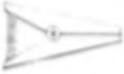


H. Soldering aid

FIGURE 32

I. Heat sink

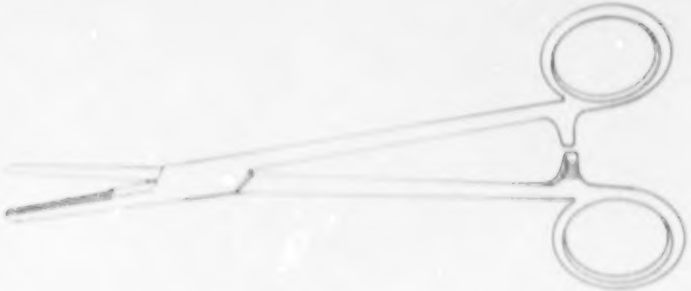
FIGURE 33



INFORMATION SHEET

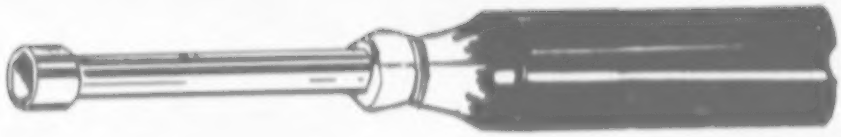
J. Hemostat

FIGURE 34



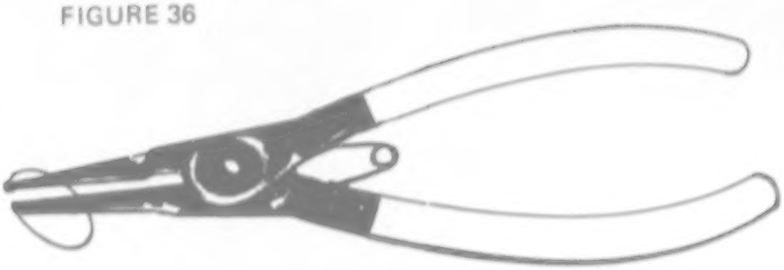
K. Nut driver

FIGURE 35



L. Snap ring pliers

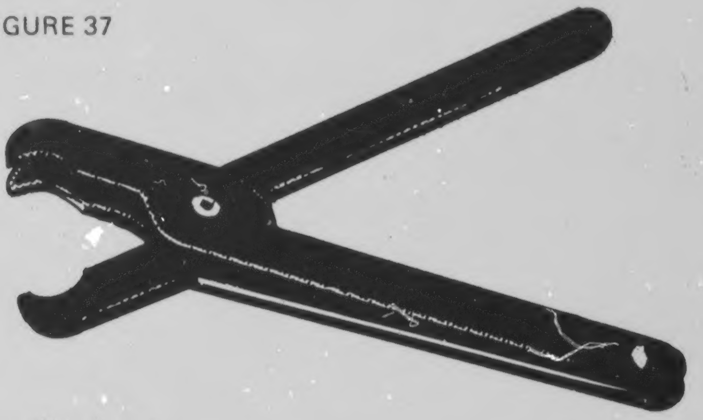
FIGURE 36



INFORMATION SHEET

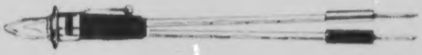
M. Fuse puller

FIGURE 37



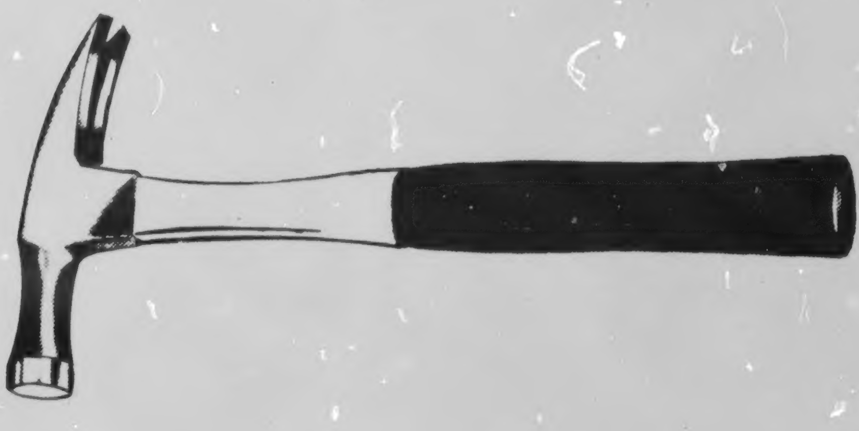
N. Circuit tester

FIGURE 38



O. Electrician's hammer

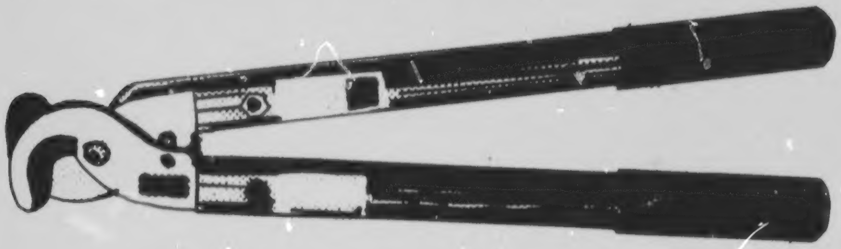
FIGURE 39



INFORMATION SHEET

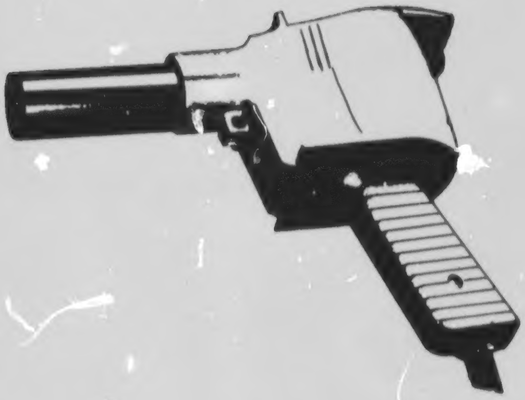
P. Cable cutter

FIGURE 40



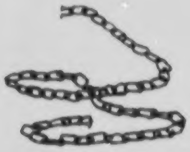
Q. Heat gun

FIGURE 41



R. Drop chain

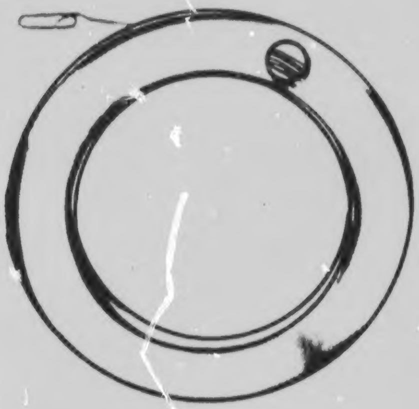
FIGURE 42



INFORMATION SHEET

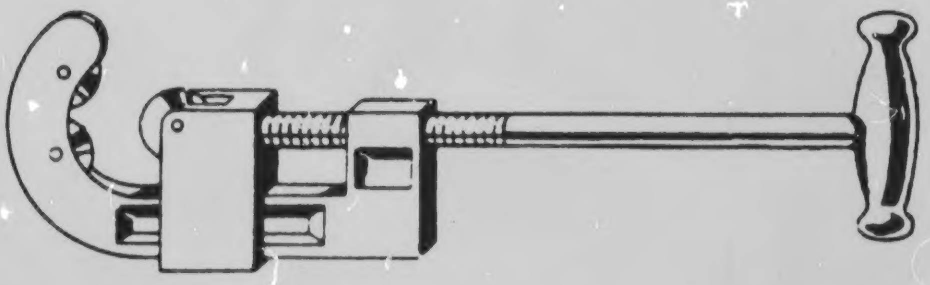
S. Fish tape and reel

FIGURE 43



T. Pipe cutter

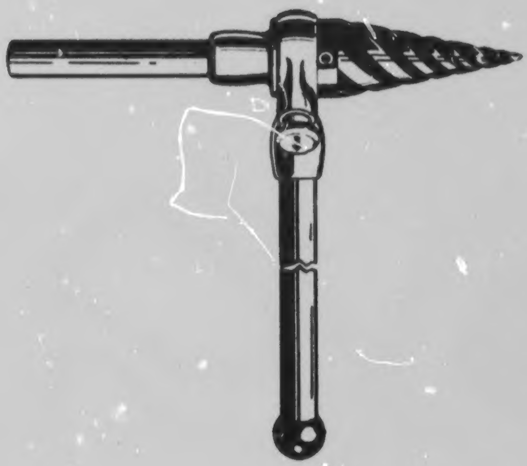
FIGURE 44



INFORMATION SHEET

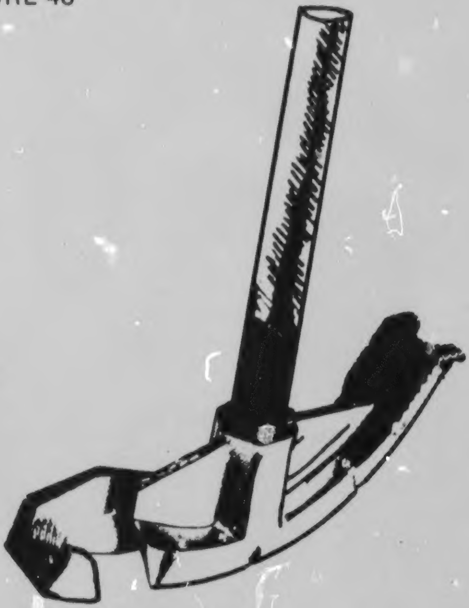
U. Pipe reamer

FIGURE 45



V. Conduit bender

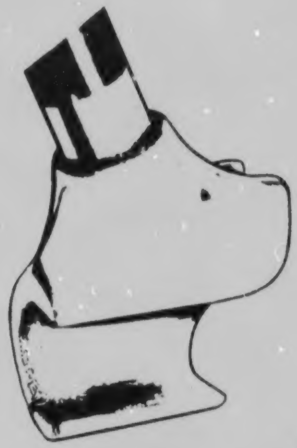
FIGURE 46



INFORMATION SHEET

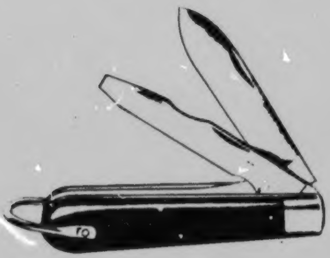
W. Hickey bender

FIGURE 47



X. Electrician's knife

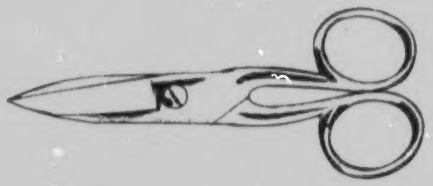
FIGURE 48



INFORMATION SHEET

Y. Electrician's scissors

FIGURE 49



IV. Common hand tools and their uses

- A. Folding rule or tape measure--Measures distances on prints, conduit, cable, and so forth
- B. Flat-blade screwdriver--Installs and/or removes slot-head screws
- C. Phillips screwdriver--Installs and/or removes Phillips-head screws
- D. Pump pliers
  1. Hold couplings and conductors
  2. Tighten couplings and conductors
  3. Hold conduit
  4. Tighten or turn conduit
- E. Adjustable wrench--Used in place of other wrenches; versatile (Transparency #1)
- F. Hacksaw
  1. Cuts large conductors or cables
  2. Cuts conduit
  3. Cuts metal for electronic cabinets

INFORMATION SHEET

G. Keyhole saw--Cuts holes in plasterboard for circuit boxes; needs no electric power

H. File

   1. Deburrs large conduit

   2. Sharpens tools

   3. Deburrs holes in circuit boxes

   4. Cleans soldering iron or soldering gun tips

I. Chisel--Notches wood for boxes or cables

J. Center punch--Makes center tap for drilling

K. Bolt cutter--Cuts large bolts, chains, locks, and so forth

L. Hex key set (Allen wrenches)--Installs and/or removes Allen screws

M. Torpedo Level

   1. Levels conduit

   2. Levels equipment

N. Knockout punch--Cuts large holes in metal boxes without drilling

   (NOTE: Thick or very hard metal cannot be cut with a knockout punch. Also, in some areas it is too inconvenient to use a knockout punch.)

O. Hole saw--Cuts large holes in metal

P. Drill brace and drill--Bores holes for conduit or cable

Q. Tap tool

   1. Equips drill holes with bolt threads

   2. Retaps damaged threads

   3. Determines bolt size

R. Drill motor and drill--Drills holes for electronic cabinets; needs electric power

S. Jigsaw (sabre saw)--Cuts holes in plasterboard; needs electric power

T. Screw-holding screwdriver--Holds screw for use in limited-space installation

INFORMATION SHEET

V. Electricity/electronics-specific hand tools and their uses

   A. Needle-nose pliers

      1. Form loops on small conductors
      2. Cut small conductors
      3. Hold conductors while soldering

   B. Diagonal pliers (dykes)

      1. Cut small conductors
      2. Cut conductors in limited space

   C. Lineman's pliers

      1. Cut large conductors
      2. Form loops on large conductors
      3. Pull and/or hold large conductors

   D. Adjustable wire stripper

      1. Strips insulation from conductors
      2. Cuts small conductors

   E. Cutting/crimping tool

      1. Strips insulation from conductors
      2. Cuts small conductors
      3. Cuts small bolts
      4. Crimps wire lugs

   F. Soldering iron (approximately 25 W)

      1. Solders small heat-sensitive components
      2. Solders on printed circuit boards

   G. Soldering gun

      1. Solders large conductors
      2. Splices cables

INFORMATION SHEET

H. Soldering aid

    1. Cleans soldering iron tips
    2. Scrapes or cleans conductors
    3. Holds conductors while soldering

I. Heat sink--Prevents excessive heat from reaching electronic components

J. Hemostat--Prevents excessive heat from reaching electronic components; used in place of heat sink

K. Nut driver

    1. Installs and/or removes nuts and bolts
    2. Tightens or loosens nuts on long bolts

L. Snap ring pliers--Install or remove snap rings on electrical equipment

M. Fuse puller--Removes fuses safely from equipment and circuit panels

(NOTE: Fuse pullers are insulated in order to prevent shock, but power must be turned off first for safety.)

N. Circuit tester (Transparency #2)

    1. Checks circuits for power
    2. Identifies conductors

O. Electrician's hammer

    1. Drives and pulls nails
    2. Opens wooden crates
    3. Breaks plasterboard

P. Cable cutter--Cuts large cables

(NOTE: Cables must be either copper or aluminum.)

Q. Heat gun

    1. Dries electronic components and/or conductors
    2. Shrinks heat shrink

R. Drop chain--Pulls cables through wall

INFORMATION SHEET

S. Fish tape and reel

  1. Pulls conductors through conduit
  2. Pulls cables through insulated walls

T. Pipe cutter-Cuts conduit

U. Pipe reamer-Deburrs conduit

V. Conduit bender--Bends conduit for conductor installation

W. Hickey bender--Bends heavy conduit

X. Electrician's knife

  1. Opens paper cartons
  2. Strips large conductors
  3. Strips cables
  4. Tightens or loosens small screws when screwdriver is not available

     (NOTE: Some electrician's knives are equipped with screwdriver blades.)

Y. Electrician's scissors

  1. Cut small conductors
  2. Remove insulation from small conductors
  3. Cut paper, heat shrink, spaghetti, calbe-tie, and so forth

VI. Factors to consider when purchasing tools

A. Size

(NOTE: Always purchase the correct sized tool for the work to be done.)

B. Design

EXAMPLES: Insulated handles, hammers with straight claws

(NOTE: Tool should be designed specifically for electrical work.)

C. Quality

(NOTE: The purchase of quality tools will save replacement cost.)

INFORMATION SHEET

VII. Rules for care of various hand tools

(NOTE: All tools should be used only for the purpose intended.)

A. Screwdrivers

1. Regrind worn or damaged flat-blade screwdrivers
2. Discard Phillips screwdrivers with damaged tips

B. Pliers

1. Keep clean and free of rust
2. Keep cutting edges sharp
3. Keep pliers working freely
4. Replace damaged handle insulation

C. Adjustable wrenches--Keep worm gears clean and lubricated

D. Cutting tools

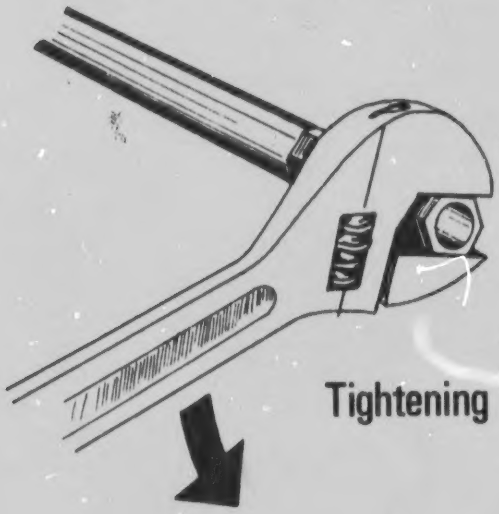
EXAMPLES: Saws, punches, chisels, drills, knives

1. Keep cutting edges sharp
2. Protect cutting edges
3. Keep tools clean and lubricated

E. Electrically powered tools

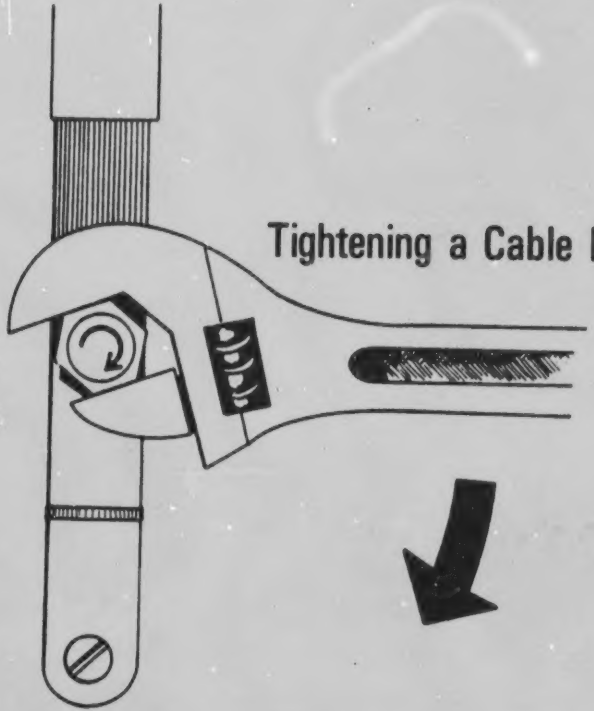
1. Replace damaged cords
2. Do not unplug by pulling cord
3. Lubricate movable parts
4. Keep clean
5. Store properly

Using an Adjustable Wrench



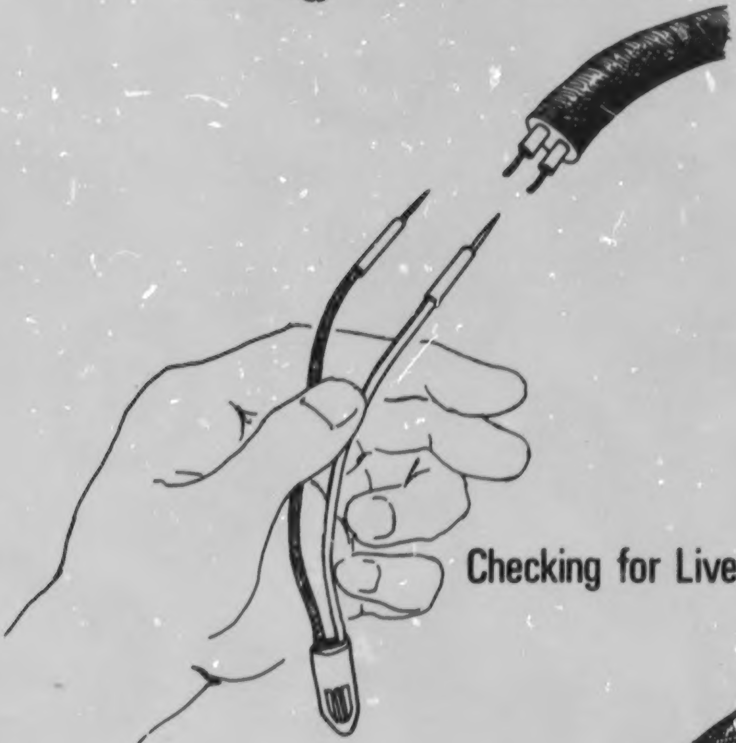
Tightening Couplings and Connectors

(Note:
Always pull away from stationary jaw to avoid breaking or damaging wrench.
Arrows indicate correct direction for wrenches in their current position.)

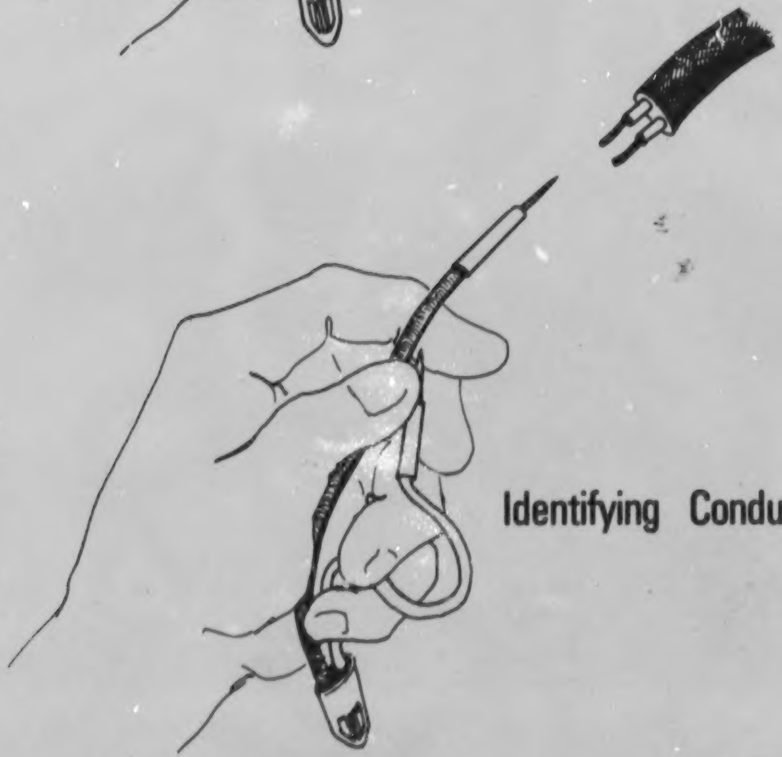


Tightening a Cable Lug

Using a Circuit Tester



Checking for Live Circuits



Identifying Conductors

HAND TOOLS
UNIT III

JOB SHEET #1--CLEAN AND LUBRICATE AN ADJUSTABLE HAND TOOL

I. Equipment and materials

- A. Pliers, or other adjustable hand tool
- B. Solvent
- C. Oil
- D. Solvent tray

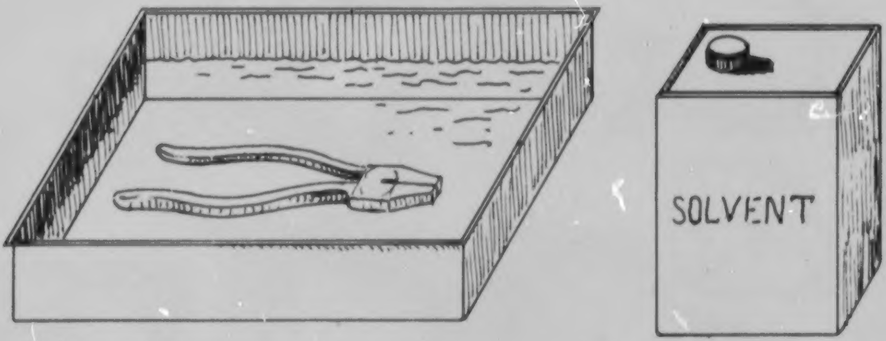
  (NOTE: An old rectangular cake pan works well.)
- E. Protective gloves
- F. Cleaning cloth

II. Procedure

- A. Put on protective gloves
- B. Lay pliers in tray
- C. Pour solvent into tray until pliers are submersed (Figure 50)

  (NOTE: If pliers are equipped with cushion grips, only the head should be immersed.)

FIGURE 50



JOB SHEET #1

D. Open and close pliers several times while submersed

E. Let pliers sit in solvent for two or three minutes

F. Remove from solvent

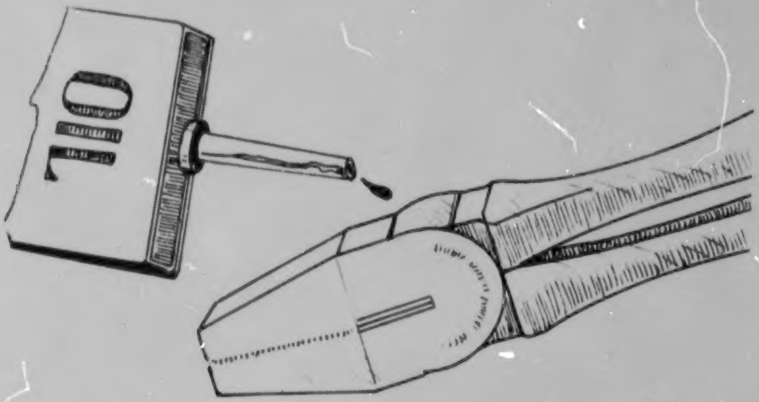
G. Open and close rapidly until pliers work freely

(NOTE: If pliers will not yet work, repeat steps B, C, D, and E.)

H. Wipe residue from plier joints with a cloth

I. Apply a couple of drops of oil to joints, and work until oil has penetrated (Figure 51)

FIGURE 51



J. Wipe excess oil from pliers

(NOTE: Have instructor check tool.)

K. Put equipment and materials away

HAND TOOLS
UNIT III

JOB SHEET #2--GRIND A FLAT-BLADE SCREWDRIVER

I. Equipment and materials

A. Flat-blade screwdriver

B. Bench grinder with adjustable tool rest

C. Water tray

D. Safety goggles or a grinding shield that covers your face

(NOTE: Even if a guard is provided, more protection than safety glasses is recommended.)

II. Procedure

A. Put on shield or goggles

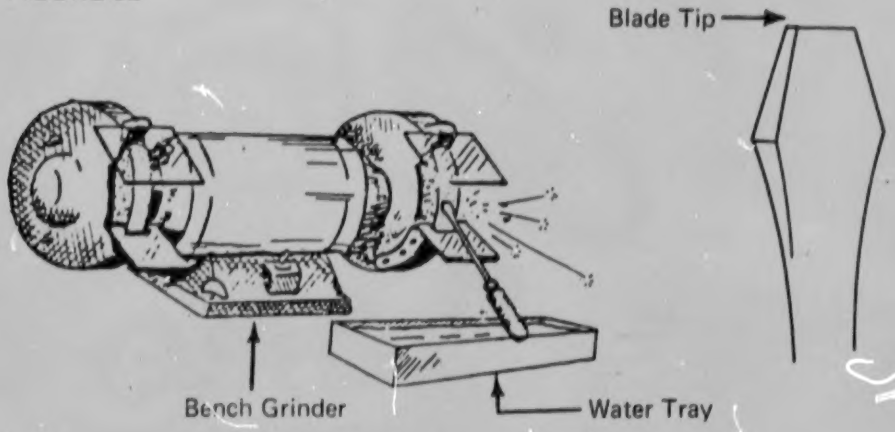
B. Adjust clearance of tool rest

(NOTE: Proper clearance is approximately one-eighth of an inch from the grinding wheel.)

C. Turn on grinder

D. Grind tip of blade flat (Figure 52)

FIGURE 52



JOB SHEET #2

E. Turn off grinder and let it come to a complete stop

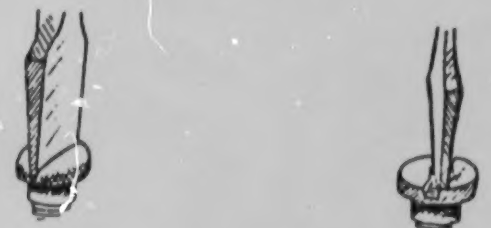
(CAUTION: Do not press any objects against the wheel to help it slow down.)

F. Readjust tool rest so that uniform grinding will occur on the flat part of the blade about one inch up the shank

G. Grind the bevel evenly on both sides until correct blade fit is reached (Figure 53)

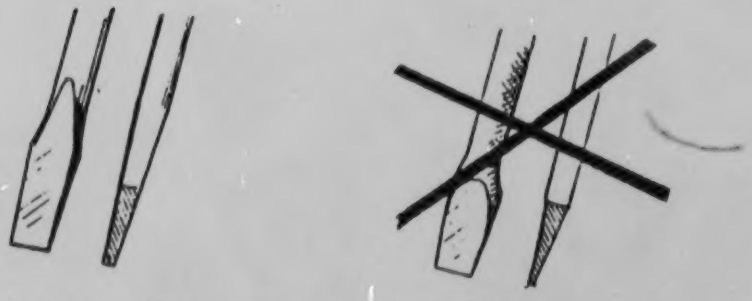
(NOTE: Tip should be cooled frequently during grinding process to maintain metal temper.)

FIGURE 53



Ground Right

Ground Wrong



H. Turn off grinder and let it come to rest before leaving it

(NOTE: Have instructor check screwdriver.)

I. Put equipment and materials away

HAND TOOLS
UNIT III

JOB SHEET #3--USE A CUTTING/CRIMPING TOOL

I. Equipment and materials

   A. Cutting/crimping tool

   B. Solid insulated conductor--12 to 18 gauge

   C. Bolt--Size 6-32, 8-32, or 10-32

   D. Wire lug--Same size as conductor

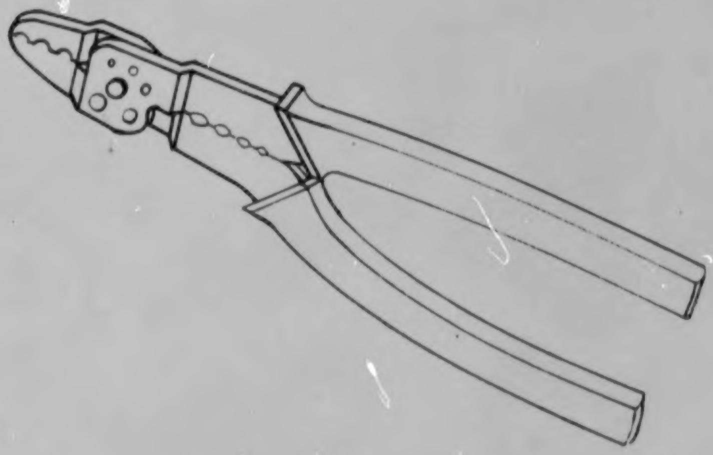
   E. Safety glasses

II. Procedure

   A. Examine cutting/crimping tool

   B. Locate stripping area of the cutting/crimping tool (Figure 54)

   FIGURE 54



   C. Locate correct-sized stripping slot for conductor

   EXAMPLES: AWG-18, AWG-20 wire size

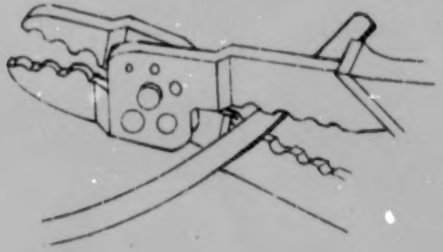
   D. Put on safety glasses

JOB SHEET #3

E. Open cutting/crimping tool and insert conductor into curved area of stripping slot (Figure 55)

(NOTE: Insert conductor approximately 1/4 inch from end of conductor.)

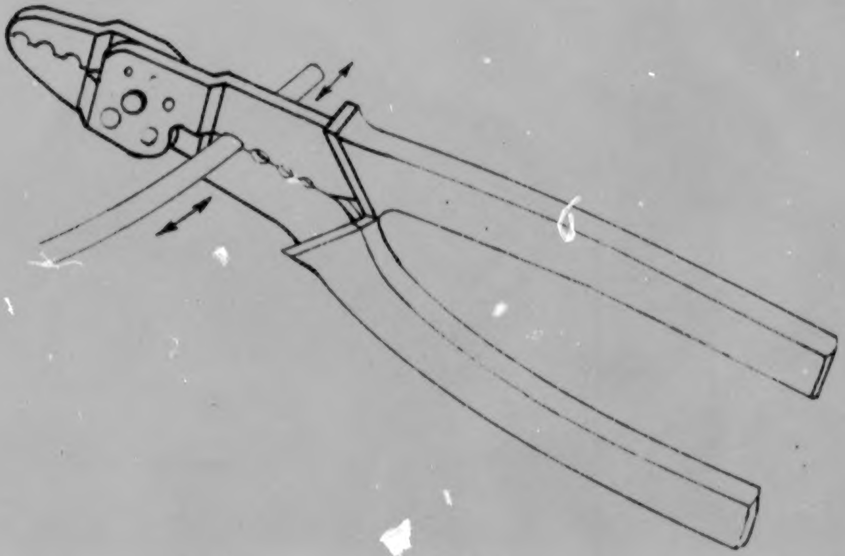
FIGURE 55



F. Slowly close cutting area by squeezing handles together

G. Hold conductor while slowly rotating cutting/crimping tool (Figure 56)

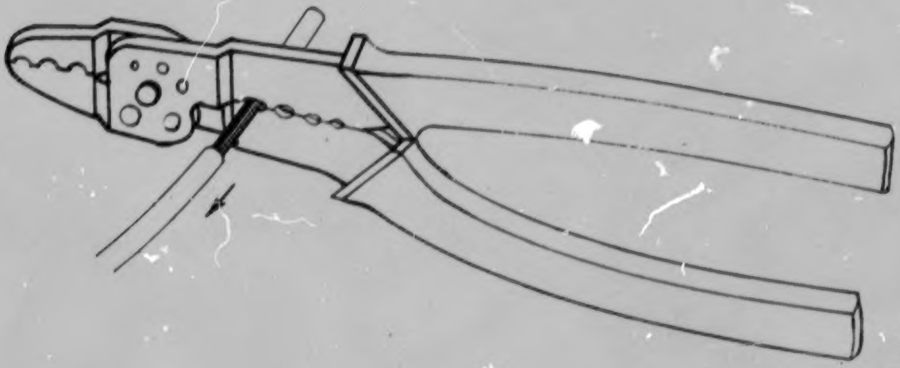
FIGURE 56



JOB SHEET #3

H. Pull conductor long lead away from cutting/crimping tool (Figure 57)

FIGURE 57

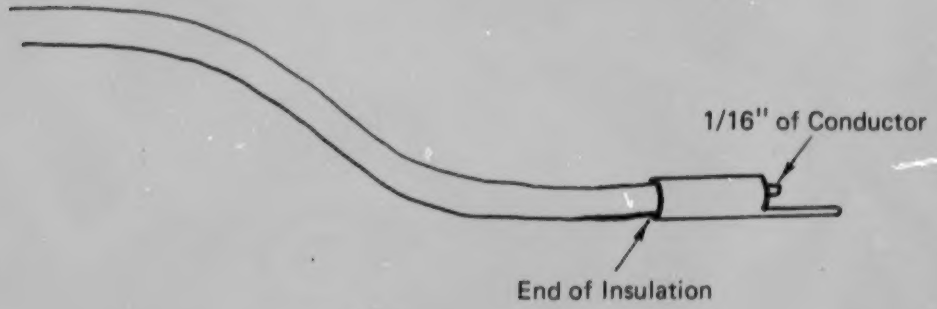


(NOTE: If the correct stripping slot was chosen, insulation should easily slide from the conductor. Have the instructor check your work.)

I. Put the wire lug on conductor (Figure 58)

(NOTE: The insulation should just touch the wire lug, and the bare conductor should protrude past the wire lug approximately one-sixteenth of an inch.)

FIGURE 58



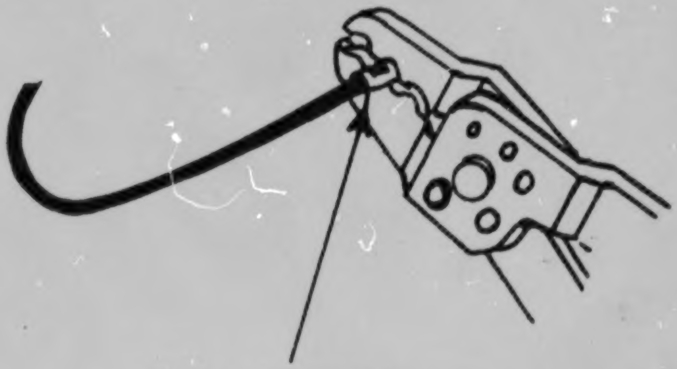
JOB SHEET #3

J. Locate correct crimping area for size wire lug being used

(NOTE: The wire gauge number, the lug number, and the crimping tool number should all be the same. See Figure 59.)

K. Insert wire lug into crimping tool, making sure lug seam is on indenting side of crimping slot (Figure 59)

FIGURE 59



Seam on Bottom of Lug

L. Squeeze the handles together

(NOTE: This will crimp the wire lug onto the conductor.)

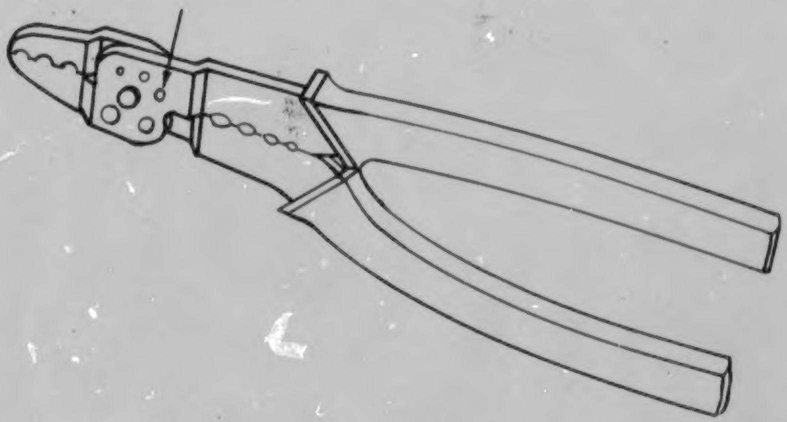
M. Remove cutting/crimping tool

(NOTE: Have instructor check your work.)

JOB SHEET #3

N. Locate bolt cutting area of cutting/crimping tool (Figure 60)

FIGURE 60



O. Locate correct cutting slot for the bolt

P. Screw bolt into cutting hole from the screw (threaded) side

(NOTE: On the cutting/crimping tool, one side is threaded and the other side is unthreaded.)

Q. Screw the bolt into the cutting/crimping tool until desired length is at center-point of cutting tool

R. Squeeze handles together until bolt is cut

(CAUTION: When bolt is cut, the unattached end may fly from cutter.)

S. Remove bolt from cutting/crimping tool

(NOTE: Have the instructor check your work.)

T. Put away equipment and materials

HAND TOOLS
UNIT III

JOB SHEET #4--ADJUST WIRE STRIPPERS

I. Equipment and materials

A. Adjustable wire strippers

B. Solid insulation conductor--12 or 14 gauge

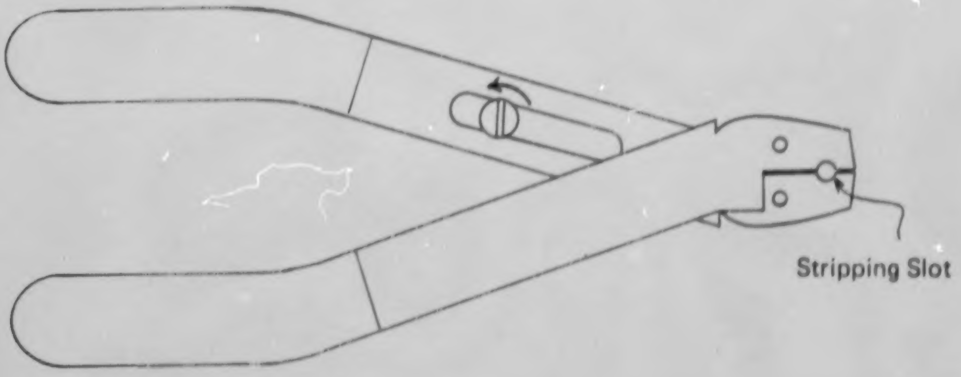
(NOTE: Strippers should be adjusted for stripping the most commonly used conductor in your area.)

C. Screwdriver or nut driver to fit adjustment screw

II. Procedure

A. Loosen adjustment screw (Figure 61)

FIGURE 61



B. Insert conductor in stripping slot

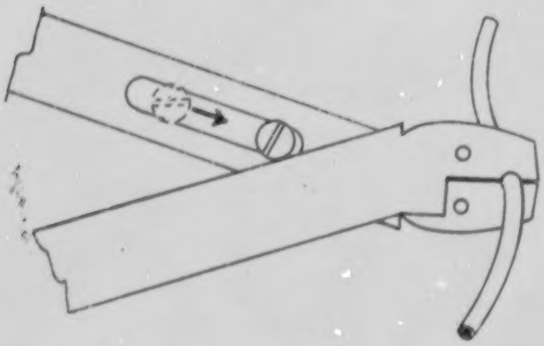
C. Close stripper jaws until you feel that you have reached the conductor

D. Open the jaws slightly

JOB SHEET #4

E. Slide adjustment screw down to its resting position (Figure 62)

FIGURE 62

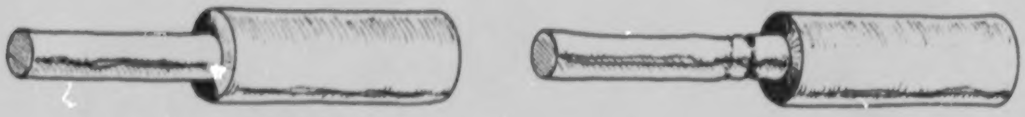


F. Strip off a fresh piece of insulation

G. Check conductor for ring or nick (Figure 63)

(NOTE: If nick occurs, loosen adjustment screw, move it back slightly, retighten, and test again until insulation is cut without conductor damage.)

FIGURE 63



Correctly Adjusted

Incorrectly Adjusted

(NOTE: Have the instructor check your work.)

H. Put away equipment and materials

HAND TOOLS
UNIT III

JOB SHEET #5--SET UP AND USE A HACKSAW

I. Equipment and materials

   A. Hacksaw frame

   B. Hacksaw blade

   (NOTE: For cutting pipe or conduit a 24 or 32 teeth/inch blade is recommended.)

   C. Pipe or conduit

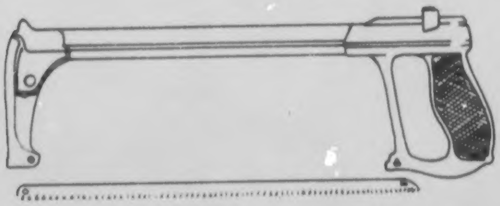
   D. Safety glasses

II. Procedure

   A. Put on safety glasses and gather tools and equipment

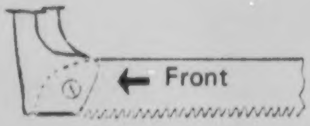
   B. Insert blade in frame (Figure 64)

FIGURE 64



(NOTE: Be sure teeth angles are pointed toward the front of the saw. Figure 65)

FIGURE 65

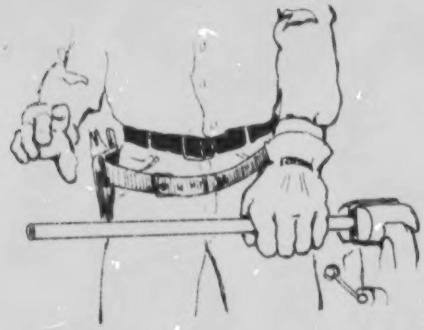


JOB SHEET #5

C. Secure pipe or conduit for cutting (Figure 66)

(NOTE: Short pieces of pipe are easier to cut in a vise.)

FIGURE 66



D. Rest blade on pipe or conduit at point to be cut

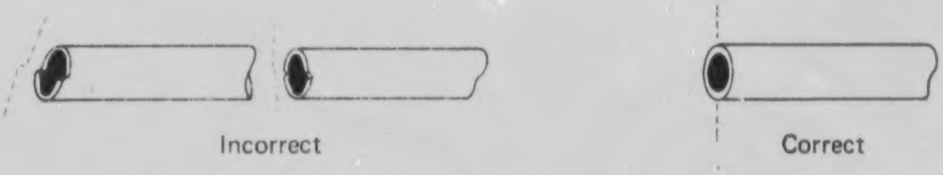
E. Push forward gently until cut is started

(NOTE: Do not exert extra pressure on saw.)

F. Make reciprocal strokes until cut is finished

(NOTE: Excessive speed while cutting can ruin blades. Do not use over thirty full strokes per minute. Your cut should be straight and relatively smooth. Figure 67.)

FIGURE 67



(NOTE: Have the instructor check your cut.)

G. Put away equipment and materials

HAND TOOLS
UNIT III

JOB SHEET #6--CUT RIGID CONDUIT WITH A PIPE CUTTER

I. Equipment and materials

   A. Pipe vise

   B. Pipe cutter

   C. Rigid conduit

   D. Cutting oil

   E. Safety glasses

   F. Shop towel

   G. Pencil

II. Procedure

   A. Put on safety glasses and gather tools and equipment

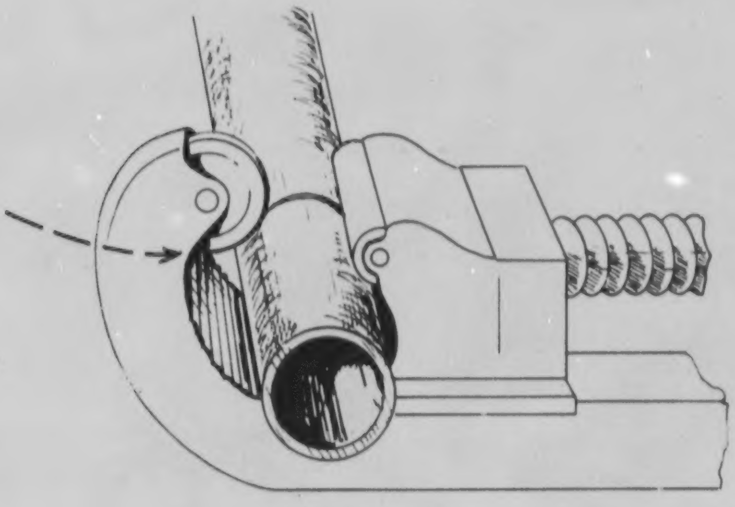
   B. Secure conduit in vise

   C. Mark place for cut with pencil

   D. Open pipe cutter until it will fit over conduit

   E. Locate cutter wheel on the pencil mark (Figure 68)

FIGURE 68

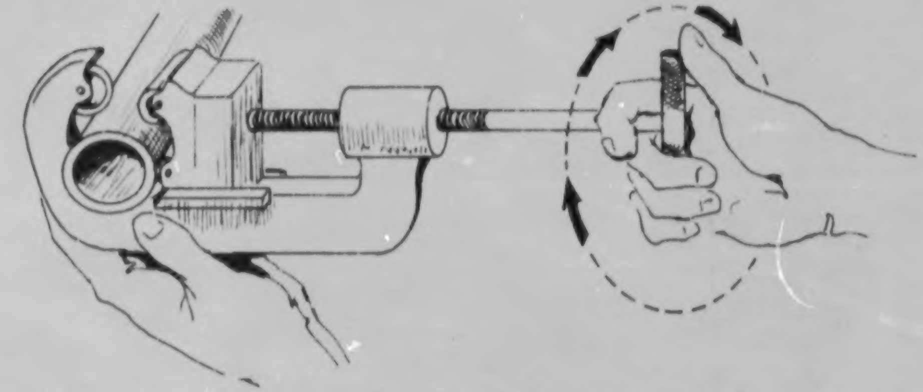


JOB SHEET #6

F. Snug cutter to conduit by rotating screw handle (Figure 69)

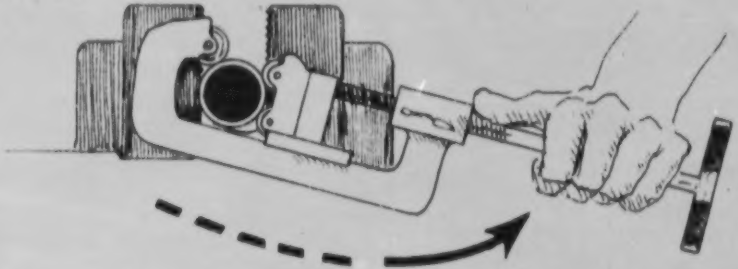
(NOTE: Do not overtighten as this can break cutter wheel.)

FIGURE 69



G. Rotate cutter counterclockwise to start groove (Figure 70)

FIGURE 70



H. Tighten cutter handle 1/4 of a turn for each full revolution around the pipe

(NOTE: Overtightening can cause cutters to break.)

I. Add a small amount of cutting oil to the groove

(CAUTION: When cutting short pieces of conduit, be careful not to cut your arm while rotating the cutter around the pipe.)

J. Continue process until conduit is cut

(NOTE: Be prepared to catch free piece of conduit.)

K. Clean conduit and cutter with shop towel

(NOTE: Have instructor inspect work.)

L. Put away equipment and materials

HAND TOOLS
UNIT III

JOB SHEET #7--REAM RIGID CONDUIT

I. Equipment and materials

A. Pipe vise

B. Reamer

(NOTE: You will need a ratchet hand or brace depending on which type reamer used.)

C. Piece of rigid conduit

D. Safety glasses

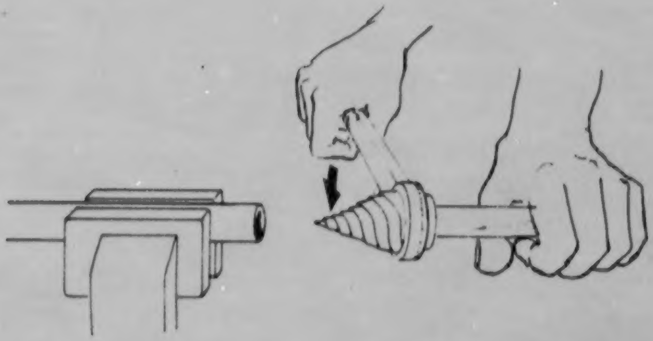
II. Procedure

(NOTE: Be safety conscious around cut pieces of rigid conduit. Sharp ridges or spurs can cause deep cuts.)

A. Place conduit in vise

B. Insert reamer tip in conduit (Figure 71)

FIGURE 71



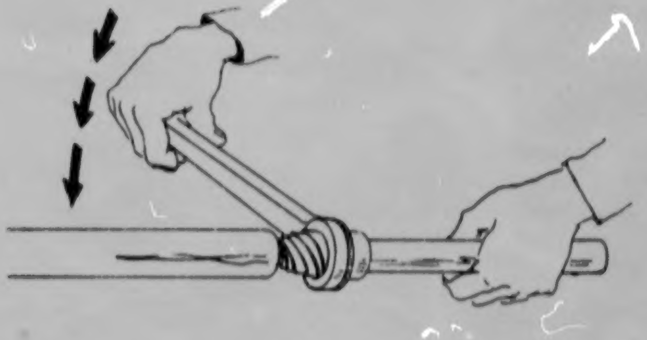
C. Apply light forward pressure to push reamer into conduit

JOB SHEET #7

D. Start rotating reamer (Figure 72)

(NOTE: Reamer should bite instantly if proper pressure is applied. Reamer can be damaged if rotated in the wrong direction.)

FIGURE 72

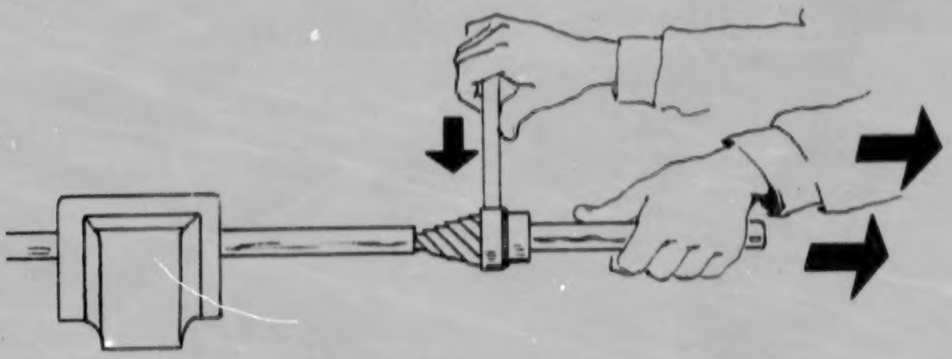


E. Rotate reamer until burrs are removed

(NOTE: This is a developed skill; the reamer can be pulled out and your progress inspected.)

F. Pull reamer back while continuing to rotate to prevent reamer from leaving a burr (Figure 73)

FIGURE 73



(NOTE: Have your instructor check your work.)

G. Put away all equipment and materials

HAND TOOLS
UNIT III

JOB SHEET #8--BEND EMT CONDUIT

(NOTE: Because of the differences in bender shoe markings, the height of this bend and its determination will be left to the instructor.)

I. Equipment and materials

   A. 1/2" EMT bender

   B. 1/2" EMT (length optional)

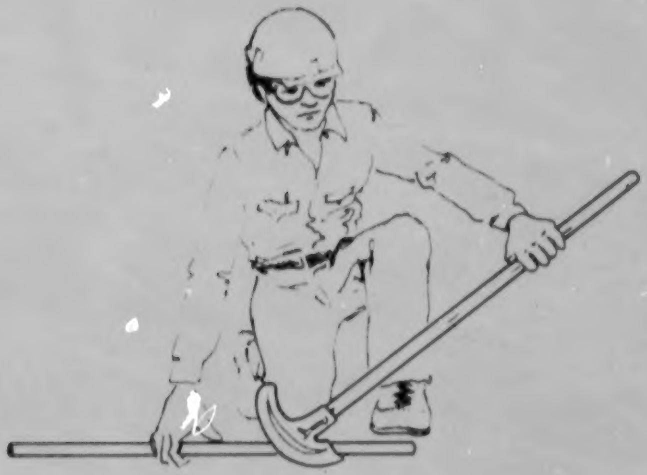
   C. Safety glasses

II. Procedure

   A. Put on safety glasses and gather tools and equipment

   B. Place conduit in bender jaw (Figure 74)

FIGURE 74



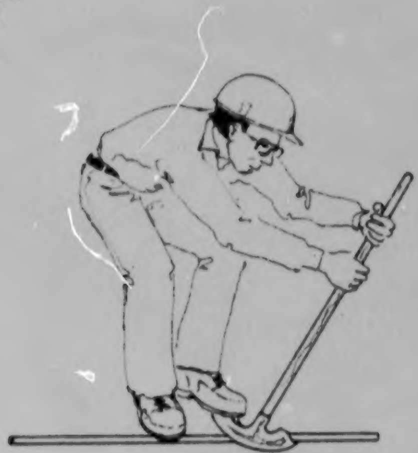
   C. Apply light pressure on handle to hold conduit in place

   D. Place one foot on bender kick pad

JOB SHEET #8

E. Place other foot on conduit (Figure 75)

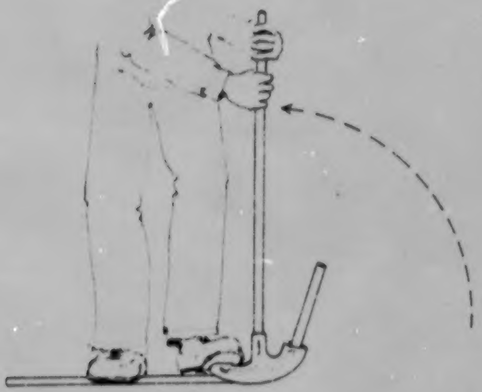
FIGURE 75



F. Apply heavy pressure on bender kick pad while pulling handle to a straight up position (Figure 76)

(NOTE: If pressure is not applied solidly to kick pad, conduit can wrinkle or collapse.)

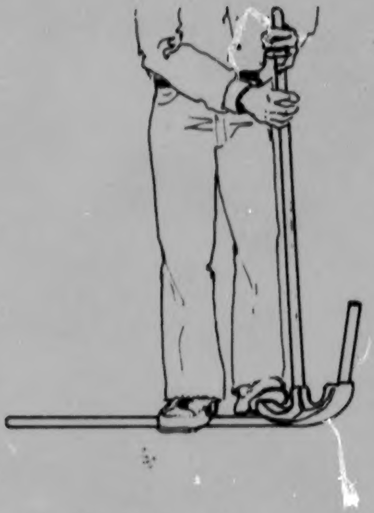
FIGURE 76



JOB SHEET #8

G. Reposition feet for comfort (Figure 77)

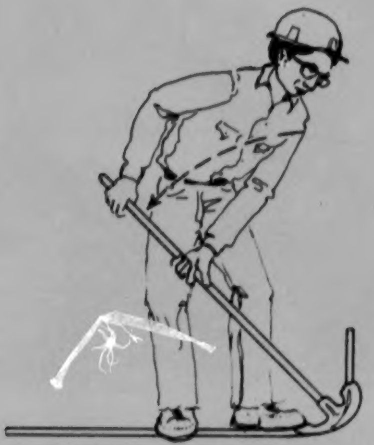
FIGURE 77



H. Reapply kick pad and bender handle pressure until bend is completed (Figure 78)

(NOTE: A square can be used to evaluate your accuracy until you develop your skills.)

FIGURE 78



(NOTE: Have instructor check your work.)

I. Put away all equipment and materials

HAND TOOLS
UNIT III

JOB SHEET #9--USE A KNOCKOUT PUNCH

I. Equipment and materials

A. Knockout punch

B. Drill motor

C. Metal drill

(NOTE: Drill must be large enough to let the knockout punch bolt though the opening it makes.)

D. 10" adjustable wrench or 1/2" ratchet with socket to fit drive nut

E. Metal to be punched

(NOTE: Most punches are rated up to 10 gauge metal.)

F. Vise

(NOTE: A vise is needed if material to be cut is not fastened to a wall or is too small to stand on to hold.)

G. Safety glasses

H. Extension cord

II. Procedure

A. Put on safety glasses and gather materials and equipment

B. In the center of the space you are going to punch, drill a hole slightly larger than the KO punch bolt

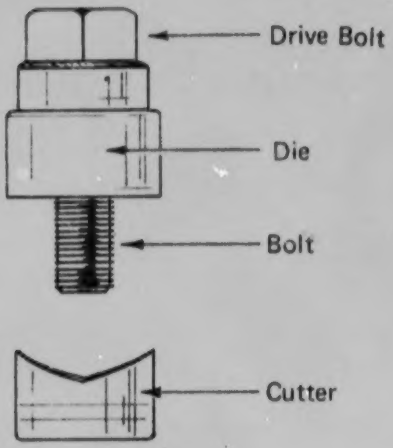
(NOTE: A center punch should be used to make an indentation for your drill to start in.)

(CAUTION: Hold the drill motor firmly while drilling. A loose grip could cause an accident. Remember that the drill will be hot; use caution around it until it cools.)

JOB SHEET #9

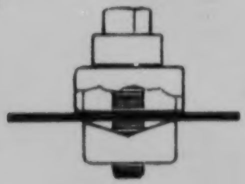
C. Separate the knockout punch cutter from the die and bolt (Figure 79)

FIGURE 79



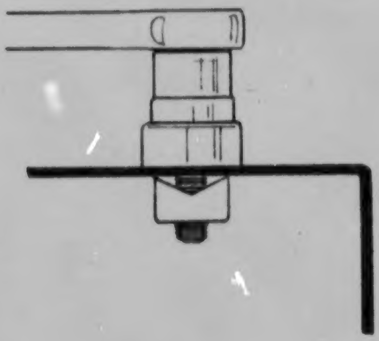
D. Insert bolt through drilled hole and put cutter back on screw (Figure 80)

FIGURE 80



E. Tighten drive bolt with wrench or socket (Figure 81)

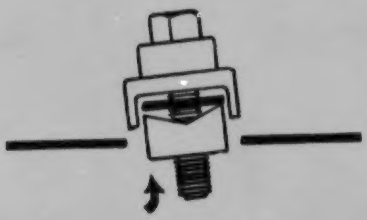
FIGURE 81



JOB SHEET #9

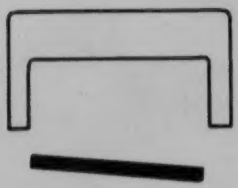
F. When cutter is finally pulled through, knockout punch is easily removed (Figure 82)

FIGURE 82



G. Remove cutter from bolt and shake out punched metal (Figure 83)

FIGURE 83



H. Lubricate cutter, if needed, and replace

(NOTE: Have instructor check your work.)

I. Put away equipment and materials

HAND TOOLS
UNIT III

JOB SHEET #10--USE A HOLE SAW

I. Equipment and materials

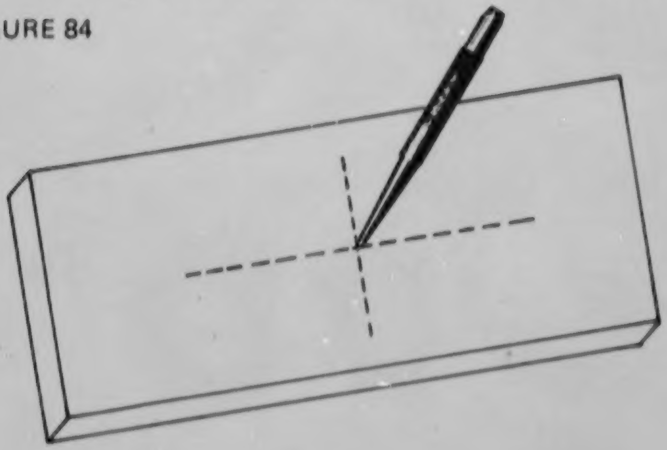
- A. Hole saw and arbor--Size determined by instructor
- B. Drill motor
- C. Center punch
- D. Metal to be cut

  (NOTE: Most hole saws can drill through any machinable material up to 1 1/8 inches thick.)
- E. Safety glasses
- F. Hammer

II. Procedure

- A. Put on safety glasses
- B. Locate point on metal where hole is to be cut
- C. Place center punch on center point of hole to be cut (Figure 84)

FIGURE 84



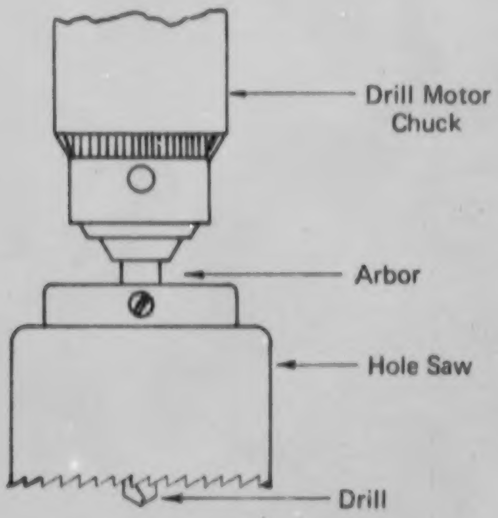
- D. Strike center punch with hammer

  (NOTE: How hard the center punch is struck is determined by the type and thickness of the metal being used. Softer, thinner metal, if struck too hard will bend easily.)

JOB SHEET #10

E. Insert hole saw arbor into the drill motor chuck (Figure 85)

FIGURE 85



(CAUTION: Be sure chuck is tight, and chuck key is removed before drilling.)

F. Place tip of drill in hole made by the center punch

(NOTE: If material to be cut is not fastened solidly, put material in vice before cutting.)

(CAUTION: While drilling, hold the drill motor firmly with both hands. The hole saw can become jammed causing the drill motor to spin.)

G. Turn on drill motor until hole saw has cut completely through metal being cut

(NOTE: Have instructor check your work.)

H. Put away equipment and materials

HAND TOOLS
UNIT III

TEST

NAME ________________________________ SCORE ________________

1. Match terms associated with hand tools to their correct definitions. Write the correct numbers in the blanks. Definitions are continued on the next page.

______a. Industrial blueprint; industrial wiring diagram

______b. Circuit with voltage applied and flowing current

______c. Metal connector crimped or soldered to a conductor; allows conductor to be fastened with a screw or bolt

______d. Nonconductive material that prevents leakage of electricity from a conductor and protects against accidental contact

______e. Device for holding a component of a tool rigid

______f. Nonconductive material placed around a conductor for insulation; does not shrink

______g. Box where electrical connections are made, usually through circuit breakers

______h. Safety device placed in a circuit; in cases of excessive current, it melts, thus opening the circuit

______i. Pipe or tube which holds and protects wires or cables

______j. Shaft or spindle used to hold a revolving cutting tool or the work to be cut

______k. Nonconductive material placed around a conductor for insulation; shrinks when heated

______l. Metal ring which fastens around or in a shaft to keep other parts stationary

______m. Mechanical device for connecting conduit and cabling

______n. Material through which electrons flow easily; used to connect components

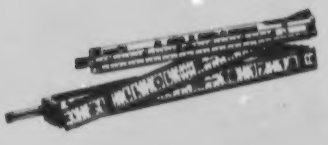
1. Print
2. Coupling
3. Conduit
4. Plasterboard
5. Circuit box
6. Insulation
7. Wire lug
8. Snap ring
9. Fuse
10. Heat shrink
11. Spaghetti
12. Cable-tie
13. Conductor
14. Live circuit
15. Chuck
16. Arbor

TEST

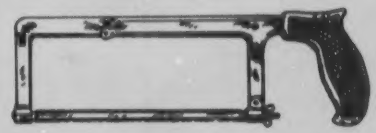
_____o. Plastic straps with pull-through fasteners for binding together conductors or cables

_____p. Thin board formed of layers of plaster and paper; sheetrock

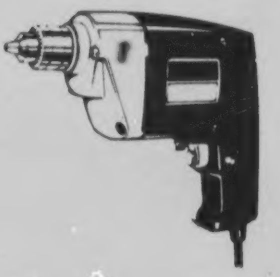
2. Label the following common hand tools used in industrial electricity/electronics. Write the correct names in the spaces provided.



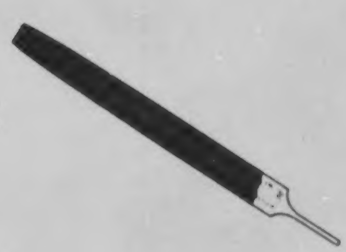
a. ________________________



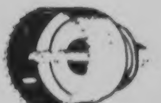
b. ________________________



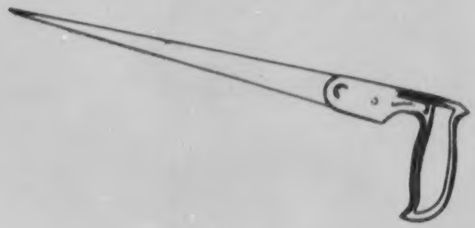
c. ________________________



d. ________________________

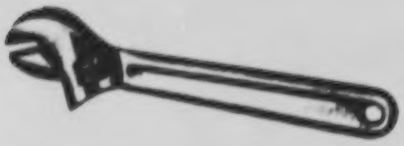


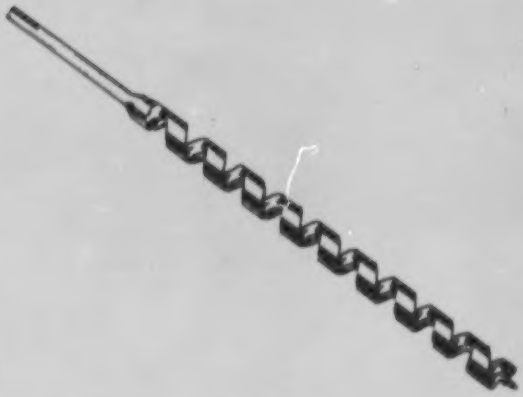
e. ________________________



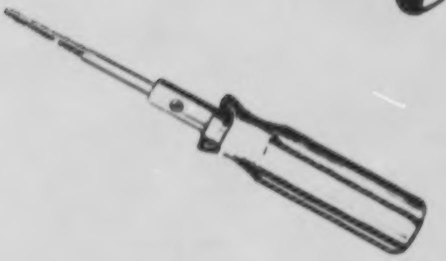
f. ________________________

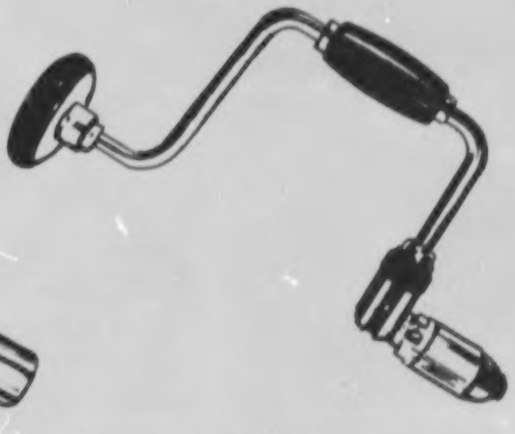
TEST



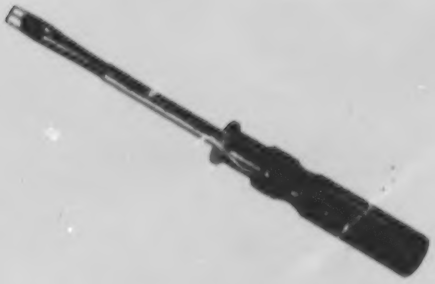


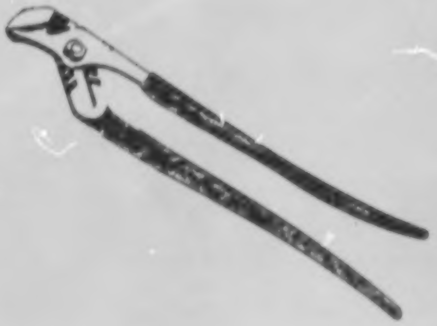
g. ____________________ h. ____________________





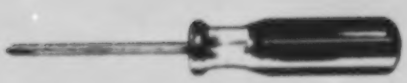
i. ____________________ j. ____________________

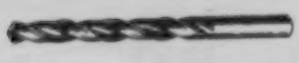




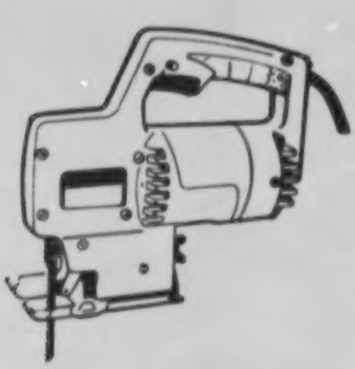
k. ____________________ l. ____________________

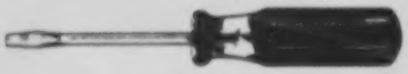
TEST



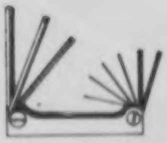


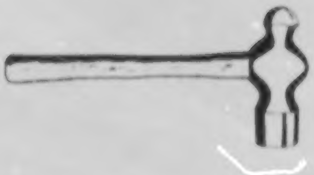
m. ______________________ n. ______________________





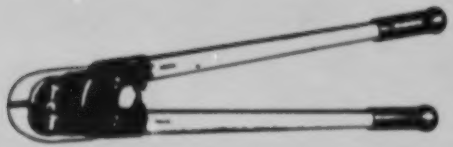
o. ______________________ p. ______________________



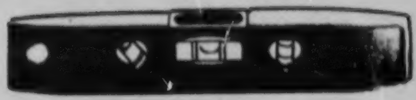


q. ______________________ r. ______________________

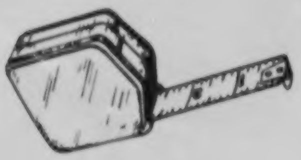
TEST



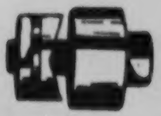
s. ______________________



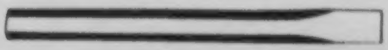
t. ______________________



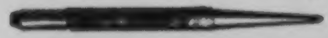
u. ______________________



v. ______________________



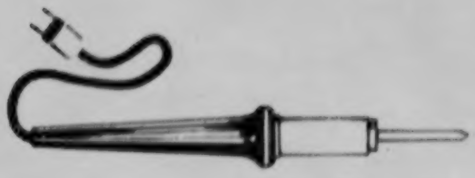
w. ______________________

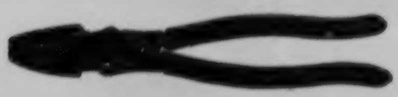


x. ______________________

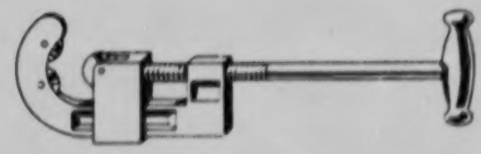
TEST

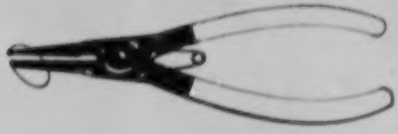
3. Label the following electricity/electronics-specific hand tools used in industrial maintenance. Write the correct names in the spaces provided.



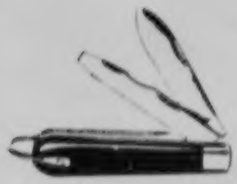


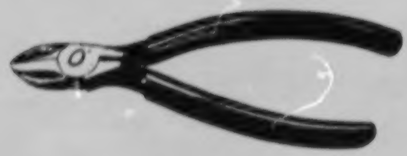
a. ______________________ b. ______________________





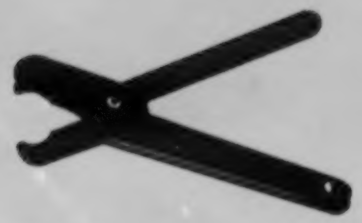
c. ______________________ d. ______________________



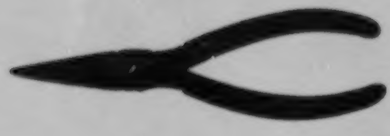


e. ______________________ f. ______________________

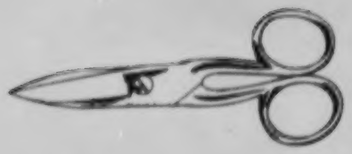
TEST



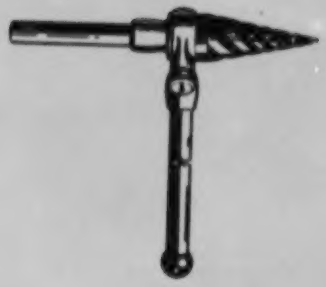
g. ________________________



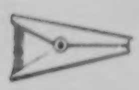
h. ________________________



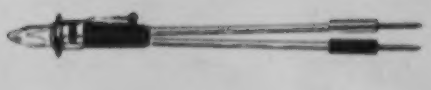
i. ________________________



j. ________________________

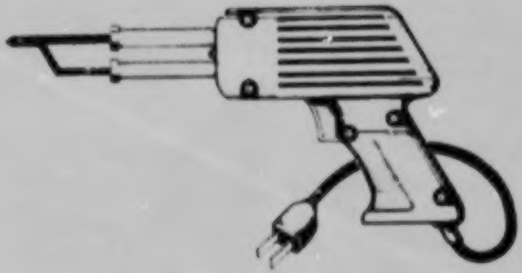


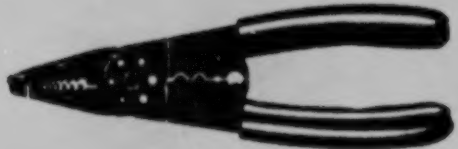
k. ________________________



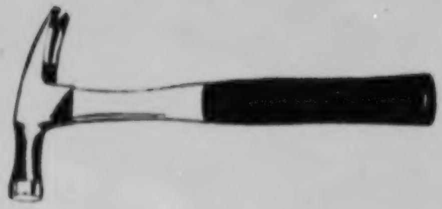
l. ________________________

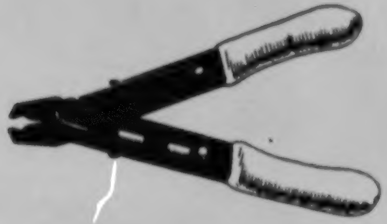
TEST



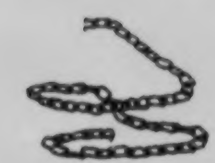


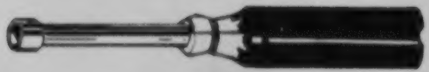
m. ______________________ n. ______________________





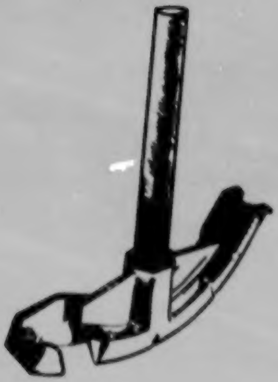
o. ______________________ p. ______________________

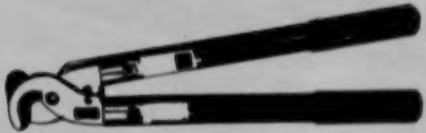




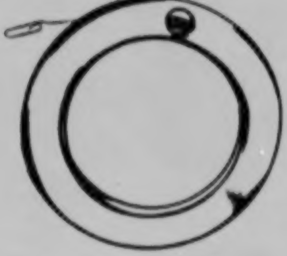
q. ______________________ r. ______________________

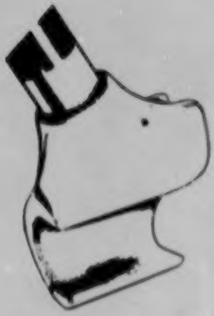
TEST



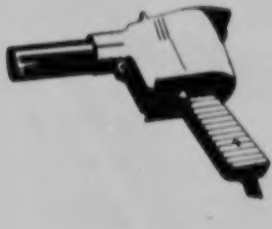


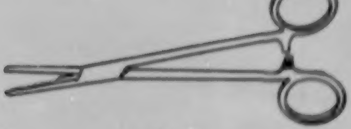
s. ____________________ t. ____________________



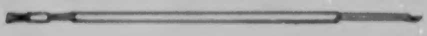


u. ____________________ v. ____________________





w. ____________________ x. ____________________



y. ____________________

TEST

4. Match common hand tools to their correct uses. Write the correct numbers in the blanks. Some numbers may be used more than once. Uses are continued on the next page.

______a. Cuts holes in plasterboard; needs electric power

______b. Makes center tap for drilling

______c. Cuts large holes in metal boxes without drilling

______d. Installs and/or removes slot-head screws

______e. Hold couplings and conductors

______f. Cuts large conductor or cables

______g. Cleans soldering iron or soldering gun tips

______h. Equips drill holes with bolt threads

______i. Drills holes for electronic cabinets; needs electric power

______j. Holds screws for use in limited-space installation

______k. Bores holes for conduit or cable

______l. Cuts large bolts, chains, locks, and so forth

______m. Levels conduit

______n. Measures distances on prints, conduit, cable, and so forth

______o. Installs and/or removes Phillips-head screws

______p. Tightens or turns conduit

______q. Cuts metal for electronic cabinets

______r. Cuts holes in plasterboard for circuit boxes; needs no electric power

______s. Deburrs large conduit

______t. Cuts conduit

______u. Installs and/or removes Allen screws

______v. Cuts large holes in metal

1. Folding rule or tape measure
2. Flat-blade screwdriver
3. Phillips screwdriver
4. Pump pliers
5. Adjustable wrench
6. Hacksaw
7. Keyhole saw
8. File
9. Chisel
10. Center punch
11. Bolt cutter
12. Hex key set (Allen wrenches)
13. Torpedo level
14. Knockout punch
15. Hole saw
16. Drill brace and drill
17. Tap tool
18. Drill motor and drill
19. Jigsaw (sabre saw)
20. Screw-holding screwdriver

TEST

______w. Levels equipment

______x. Retaps damaged threads

______y. Notches wood for boxes or cables

______z. Determines bolt size

______aa. Sharpens tools

______bb. Tighten couplings and connectors

______cc. Used in place of other wrenches; versatile

______dd. Deburrs holes in circuit boxes

______ee. Hold conduit

5. Match electricity/electronic-specific hand tools to their correct uses. Write the correct numbers in the blanks. Some numbers may be used more than once. Tools and uses are continued on the next page.

______a. Cut(s) small conductors

______b. Deburrs conduit

______c. Drives and pulls nails

______d. Shrinks heat shrink

______e. Removes fuses safely from equipment and circuit panels

______f. Cuts small bolts

______g. Cleans soldering iron tips

______h. Prevents excessive heat from reaching electronic components

______i. Splices cables

______j. Crimps wire lugs

______k. Install or remove snap-rings on electrical equipment

______l. Identifies conductors

______m. Pulls cables through wall

______n. Pulls cables through insulated walls

______o. Bends conduit for conductor installation

1. Needle-nose pliers
2. Diagonal pliers (dykes)
3. Lineman's pliers
4. Adjustable wire stripper
5. Cutting/crimping tool
6. Soldering iron (approximately 25 W)
7. Soldering gun
8. Soldering aid
9. Heat sink
10. Hemostat
11. Nut driver
12. Snap ring pliers
13. Fuse puller
14. Circuit tester

TEST

______p. Installs and/or removes nuts and bolts

______q. Opens wooden crates

______r. Bends heavy conduit

______s. Cuts conduit

______t. Cut paper, heat shrink, spaghetti, cable-tie, and so forth

______u. Form loops on small conductors

______v. Cut large conductors

______w. Strips insulation from conductors

______x. Solders large conductors

______y. Opens paper cartons

______z. Scrapes or cleans conductors

______aa. Strips large conductors

______bb. Holds conductors while soldering

______cc. Prevents excessive heat from reaching electronic components; used in place of heat sink

______dd. Tightens or loosens nuts on long bolts

______ee. Checks circuits for power

______ff. Cuts large cables

______gg. Pulls conductors through conduit

______hh. Dries electronic components and/or conductors

______ii. Tightens or loosens small screws when a screwdriver is not available

______jj. Breaks plasterboard

______kk. Solders small heat-sensitive components

______ll. Form loops on large conductors

_____mm. Strips cables

(NOTE: Uses are continued on the next page.)

15. Electrician's hammer
16. Cable cutter
17. Heat gun
18. Drop chain
19. Fish tape and reel
20. Pipe cutter
21. Pipe reamer
22. Conduit bender
23. Hickey bender
24. Electrician's scissors
25. Electrician's knife

TEST

______nn. Solders on printed circuit boards

______oo. Cut conductors in limited space

______pp. Pull and/or hold large conductors

6. List threee factors to consider when purchasing tools.

   a. ______________________________

   b. ______________________________

   c. ______________________________

7. List rules for care of various hand tools.

   a. Screwdrivers

      1) ______________________________

      2) ______________________________

   b. Pliers

      1) ______________________________

      2) ______________________________

      3) ______________________________

      4) ______________________________

   c. Adjustable wrenches-- ______________________________

   d. Cutting tools

      1) ______________________________

      2) ______________________________

      3) ______________________________

   e. Electrically powered tools

      1) ______________________________

      2) ______________________________

      3) ______________________________

      4) ______________________________

      5) ______________________________

TEST

(NOTE: Test question 8 lists the job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

8. Demonstrate the ability to

   a. Clean and lubricate an adjustable hand tool.

   b. Grind a flat-blade screwdriver.

   c. Use a cutting/crimping tool.

   d. Adjust wire strippers.

   e. Set up and use a hacksaw.

   f. Cut rigid conduit with a pipe cutter.

   g. Ream rigid conduit.

   h. Bend EMT conduit.

   i. Use a knockout punch.

   j. Use a hole saw.

HAND TOOLS
UNIT III

ANSWERS TO TEST

1. a. 1
b. 14
c. 7
d. 6
e. 15
f. 11
g. 5
h. 9
i. 3
j. 16
k. 10
l. 8
m. 2
n. 13
o. 12
p. 4

2. a. Folding rule
b. Hacksaw
c. Drill motor
d. File
e. Hole saw and arbor
f. Keyhole saw
g. Adjustable wrench
h. Ship auger drill bit
i. Tap tool
j. Drill brace
k. Screw-holding screwdriver
l. Pump pliers
m. Phillips screwdriver
n. Drill bit
o. Flat-blade screwdriver
p. Jigsaw (sabre saw)
q. Hex key set (Allen wrenches)
r. Ball peen hammer
s. Bolt cutter
t. Torpedo level
u. Tape measure
v. Knockout punch
w. Chisel
x. Center punch

ANSWERS TO TEST

3. a. Soldering iron (approximately 25 W)
b. Lineman's pliers
c. Pipe cutter
d. Snap ring pliers
e. Diagonal pliers (dykes)
f. Fuse puller
g. Needle-nose pliers
h. Electrician's scissors
i. Pipe reamer
j. Heat sink
k. Circuit tester
l. Soldering gun
m. Cutting/crimping tool
n. Electrician's hammer
o. Adjustable wire stripper
p. Drop chain
q. Nut driver
r. Conduit bender
s. Cable cutter
t. Fish tape and reel
u. Hickey bender
v. Heat gun
w. Hemostat
x. Soldering aid

4. a. 19
b. 10
c. 14
d. 2
e. 4
f. 6
g. 8
h. 17
i. 18
j. 20
k. 16
l. 11
m. 13
n. 1
o. 3
p. 4
q. 6
r. 7
s. 8
t. 6
u. 12
v. 15
w. 13
x. 17
y. 9
z. 17
aa. 8
bb. 4
cc. 5
dd. 8
ee. 4

5. a. 1,2,24,5
b. 21
c. 15
d. 17
e. 13
f. 5
g. 8
h. 9, 10
i. 7
j. 5
k. 12
l. 14
m. 18
n. 19
o. 22
p. 11
q. 15
r. 23
s. 20
t. 24
u. 1
v. 3
w. 4, 5
x. 7
y. 25
z. 8
aa. 25
bb. 8, 1

ANSWERS TO TEST

cc. 10
dd. 11
ee. 14
ff. 16
gg. 19
hh. 17
ii. 25
jj. 15
kk. 6
ll. 3
mm. 25
nn. 6
oo. 2
pp. 3

6. a. Size
   b. Design
   c. Quality
7. a. Screwdrivers
      1) Regrind worn or damaged flat-blade screwdrivers
      2) Discard Phillips screwdrivers with damaged tips
   b. Pliers
      1) Keep clean and free of rust
      2) Keep cutting edges sharp
      3) Keep pliers working freely
      4) Replace damaged handle insulation
   c. Adjustable wrenches--Keep worm gears clean and lubricated
   d. Cutting tools
      1) Keep cutting edges sharp
      2) Protect cutting edges
      3) Keep tools clean and lubricated
   e. Electrically powered tools
      1) Replace damaged cords
      2) Do not unplug by pulling cords
      3) Lubricate movable parts
      4) Keep clean
      5) Store properly
8. Performance skills evaluated to satisfaction of instructor

ATOMS AND MATERIALS
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to identify the parts of the atom and discuss the relationship between valence electrons, heat, impurities, and conductivity of conductors, insulators, and semiconductors. This knowledge will be shown by completing assignment sheets, job sheet, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with atoms and materials to their correct definitions.
2. Match terms associated with electrical circuitry to their correct definitions.
3. Identify parts of the atom.
4. Name properties of materials affected by valence electrons.
5. Match the building blocks of matter to their correct descriptions.
6. Discuss the relationship between valence electrons and conductivity in conductors, semiconductors, and insulators.
7. Describe the effects of heat on conductors, semiconductors, and insulators.
8. Describe the effects of impurities on conductors, semiconductors, and insulators.
9. Classify kinds of conductors, semiconductors, and insulators.
10. Match methods of preventing corrosion to their correct results.
11. Make sketches of simple atoms.
12. Identify the building blocks of matter.
13. Demonstrate the ability to measure conduction and observe changes.

ATOMS AND MATERIALS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

- A. Provide students with objective sheet.
- B. Provide students with information, assignment, and job sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Demonstrate and discuss procedures outlined in assignment and job sheets.
- G. Assemble and display some of the items discussed in this unit.

  EXAMPLES: Transistors, contact paste, solder flux, copper and aluminum wires, ceramic insulators

- H. Give test.

II. Instructional materials

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  1. TM #1--Electron Shells
  2. TM #2--Electron Shells (continued)
  3. TM #3--Parts of the Atom
  4. TM #4--Building Blocks of Matter
- D. Assignment sheets
  1. Assignment Sheet #1--Make Sketches of Simple Atoms
  2. Assignment Sheet #2--Identify the Building Blocks of Matter
- E. Answers to assignment sheets
- F Job Sheet #1--Measure Conduction and Observe Changes
- G. Test
- H. Answers to test

SUGGESTED ACTIVITIES

III. Unit references

A. Eblin, Lawrence P. *Chemistry: A Survey of Fundamentals.* New York: Harcourt, Brace and World, Inc., 1968.

B. Van Vlack, Lawrence H. *Materials Science for Engineers.* Reading, Massachusetts: Addison-Wesley Publishing Company, 1970.

ATOMS AND MATERIALS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Atom--Smallest particle of an element; particles that bind together to form molecules

B. Atomic bonding--Linking together of two or more atoms to form molecules

C. Negative ions--Atoms or molecules having extra electrons causing them to have a negative charge; also called *anions*

D. Positive ions--Atoms or molecules that have lost electrons, causing them to have a positive charge; also called *cations*

E. Charge--Condition or state of having excess or insufficient number of electrons; causes the atom or molecule to be negative or positive

F. Compound--Substance made of two or more elements atomically bonded together

G. Crystal--Material in which atoms and molecules are rigidly held in a distinct orderly arrangement

H. Electron--Negatively-charged, subatomic particle that orbits around the nucleus of an atom and can be separated from atoms to flow as electricity

I. Element--One of over 100 basic materials, each made of a distinct atom; combines to form substances, mixtures, and compounds

J. Homogeneous--Made of substances that mix perfectly and blend together so that they are not individually observable in the mixture

K. Impurity--Foreign material that enters into an otherwise relatively pure substance

L. Ion--Atom or molecule that has an excess or insufficient number of electrons and, thus, is electrically unbalanced or charged

M. Molecule--Smallest particle of a compound; made of two or more identical or different atoms

N. Negative--Electrical charge of the electron; attracts protons

O. Neutron--Neutrally-charged, subatomic particle found in the nucleus of atoms

P. Nucleus--Core of the atom composed of protons and neutrons around which electrons orbit

INFORMATION SHEET

Q. Oxide--Compound of oxygen atoms and other atoms

R. Valence ring--The outermost shell of the atom

S. Valence electrons--Electrons whose orbits are contained in the outer shell

T. Proton--Positively-charged, subatomic particle found in the atom's nucleus

U. Positive--Electrical charge of the proton; attracts electrons

V. Shell--Spherical surface formed around the atom nucleus by electron orbits at distinct distances from the nucleus (Transparency #1)

(NOTE: The number of electrons orbiting in each shell of the atom is determined by the atomic number of the element and the maximum number of electrons each shell is capable of holding. This maximum number is determined by the formula, shell number squared times two, [N^2 x 2].)

W. Solution--Homegeneous mixture

II. Terms and definitions associated with electrical circuitry

A. Arcing--Occurrence of electrical sparks; visible electrical flashes

B. Conductor--Material through which electrons flow easily

C. Conductivity--Measurement of material's ability to allow electron flow

D. Contact area--Area of connectors or terminals that mates to other connectors or terminals through which electricity passes

E. Contact paste--Substance used on large electrical connections to aid flow of electricity across connection

F. Corrosion--Result of metal reacting with other elements and producing scale, film, and deterioration

G. Electricity--Flowing of electrons

H. Electrical short circuit--Electricity flowing through an unintentional path

I. Flux--Substance used to improve soldering process; acts as a chemical metal cleaner and aids in heat conduction during soldering; also known as *solder paste*

J. Insulator--Material restricting electron flow

K. Semiconductor--Material that is not a good conductor or a good insulator but will conduct variously under different conditions

INFORMATION SHEET

L. Solid-state diode--Device made of semiconductor material; used in electronic equipment

M. Solder--Alloy of soft metals, usually tin and lead, used to fuse electrical conductors

N. Transistor--Electronic device made of semiconductor material that amplifies electrical signals

III. Parts of the atom (Transparency #3)

- A. Nucleus
  - 1. Protons
  - 2. Neutrons
- B. Electrons
- C. Valence ring

(NOTE: Negatively charged electrons are attracted to positively charged protons. This tends to keep electrons attached to the atom.)

IV. Properties of materials affected by valence electrons

A. Electrical conductivity

EXAMPLE: Loosely held valence electrons account for the conductivity of metals

B. Atomic bonding

EXAMPLE: The number of valence electrons in the oxygen atom explain its corrosive effect on metals

C. Molecular structure

EXAMPLE: Valence electrons determine crystal structure of transistor materials

V. Building blocks of matter (Transparency #4; Assignment Sheet #2)

A. Atoms--Made of electrons, protons, and neutrons combined in various proportions to form over 100 types which constitute the elements

EXAMPLES: Chlorine, soduim, oxygen, hydrogen

B. Molecules--Formed by combining atoms of the same element or of different elements

EXAMPLES: Two oxygen atoms combine to form an oxygen molecule; two oxygen atoms combine with one hydrogen atom to form a water molecule

INFORMATION SHEET

C. Ions--Result of atoms or molecules either gaining or losing electrons to become charged

D. Negative ions--Negatively-charged; have extra electrons

E. Positive ions--Positively charged; are short of electrons

EXAMPLES: When a chlorine atom comes in contact with a sodium atom, it captures one of the sodium atom's electrons; thus, the sodium becomes a positive ion, and the chlorine becomes a negative ion

F. Compounds--Formed by the combinations of atoms and molecules of different elements

EXAMPLES: A water molecule is a compound because its atoms are of two different elements, but an oxygen molecule is not a compound because its atoms are of the same element

G. Mixtures-Result of elements, compounds, or substances mixed together without losing their individual characteristics

EXAMPLES: Air is a mixture of oxygen, nitrogen, hydrogen, and other elements. Salt and sand together would form a mixture

H. Solutions--Formed by homogeneous mixtures

EXAMPLES: Salt dissolved in water makes a solution because the mixture becomes homogeneous; salt and sand cannot form a solution because the two particles remain visibly distinct

VI. Relationship between valence electrons and conductivity in conductors, semiconductors, and insulators

A. Conductors--Valence electrons are loosely attached to the atom and easily separate to flow as electricity

EXAMPLES: Copper, aluminum, steel

B. Semiconductors--Valence electrons are more strongly attached to the atom and will separate only if enough voltage is applied

EXAMPLES: Silicon, germanium, selenium

C. Insulators--Valence electrons are very strongly attached to the atom and require applying tremendous force to become separated

EXAMPLES: Porcelain, glass, nylon

INFORMATION SHEET

VII. Effects of heat on conductors, semiconductors, and insulators

A. Conductors--Heat increases resistance by causing loosely assembled metal atoms to vibrate violently and disrupt the usually unimpaired electron flow

(NOTE: Because of the effects of heat, motors, generators, and electrical equipment must be kept cool in order to operate effectively.)

B. Semiconductors--Heat decreases resistance by causing strongly attached electrons to become separated more easily from the atom

(NOTE: Above normal heat will destroy semiconductors used in transistors and solid-state diodes. Because heat creates more electron flow which in turn creates more heat, devices will quickly become overheated.)

C. Insulators--Moderate amounts of heat have little effect on good insulators; however, prolonged exposure to heat will cause many insulating materials to harden, become brittle, crack, peel, and often become semiconductors

(NOTE: Printed circuit boards, wire insulation, and plastic insulators that have black, burnt, chalky areas may act as electrical short circuits.)

VIII. Effect of impurities on conductors, semiconductors, and insulators

A. Conductors--Decrease conductivity due to disruption in the normal flow of electrons; also impurities combine with conductor atoms and help secure electrons into molecules where they are not as easily separated

EXAMPLE: Corrosion on wires and terminals greatly decreases conductivity

B. Semiconductors--Aid the flow of electrons and transform these into conductors

EXAMPLE: Transistors are made of semiconductors with particular impurities added

C. Insulators--Assist the flow of electrons and transform these into semiconductors

EXAMPLE: Pure water is an insulator, but because water dissolves and absorbs impurities so well, it is a good conductor unless carefully distilled

INFORMATION SHEET

IX. Kinds of conductors, semiconductors, and insulators

- A. Conductors
  1. Gold
  2. Silver
  3. Copper
  4. Aluminum
  5. Cadmium
  6. Mercury
- B. Semiconductors
  1. Carbon
  2. Germanium
  3. Silicon
  4. Selenium
- C. Insulators
  1. Porcelain
  2. Mica
  3. Nylon
  4. Vinyl
  5. Bakelite
  6. Oil

X. Methods of preventing corrosion and their results

A. Cleaning contact areas before assembly--Reduces heat that aids corrosion; eliminates foreign material between contacts which can cause corrosion

(NOTE: The dull finish on the surface of aluminum, copper, lead, and other materials exposed to the air for extended periods of time is an oxide of metal which acts as an insulator. This dull finish should be removed down to the bright metal before assembling connection.)

B. Tightening connections--Prevents loose connectors which generate heat, thus aiding corrosion; prevents electrical arcing between loose connectors which causes rapid corrosion of metals

INFORMATION SHEET

C. Using contact paste--Aids in electrical conduction across the connection; seals air from metal surfaces

D. Using correct solder and flux--Makes better connections; eliminates corrosive effects of acids and chemicals intended for nonelectrical soldering

E. Using correct connectors--Eliminates corrosion caused by joining different metals without using special connector

F. Maintaining sealed enclosures of special gases--Replaces corrosive air with noncorrosive gas

EXAMPLE: Nitrogen

(NOTE: Telephone wire conduits, some relay enclosures, and computer memory systems are often sealed with nitrogen gas inside.)

G. Using correct electrical equipment enclosures--Keeps out corrosive elements by using weatherproof enclosures for outdoor use, waterproof enclosures in damp and humid places, and completely sealed enclosures in areas with oil, fumes, smoke, or dust

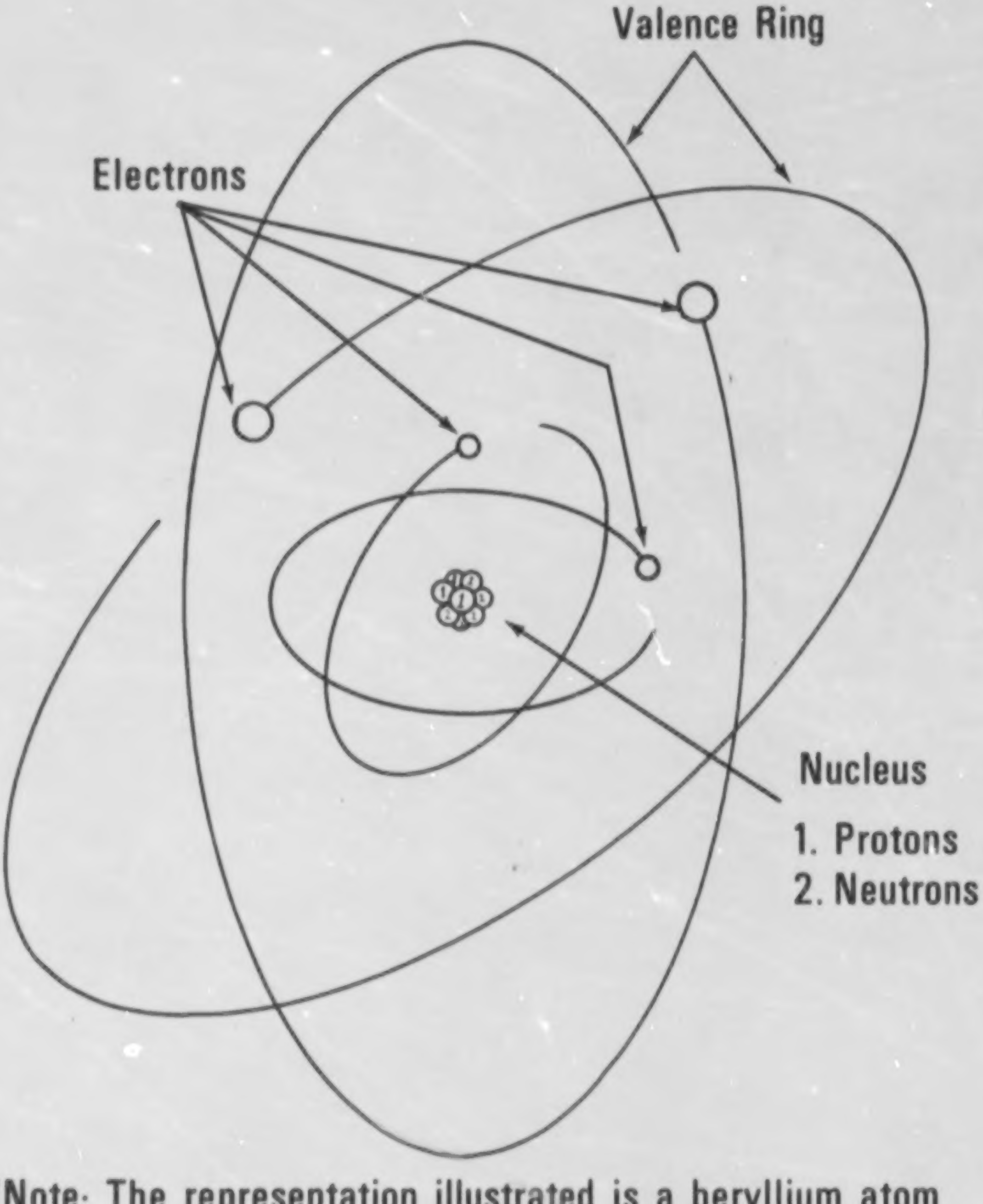
Electron Shells

Element	Atomic No.	Symbol	Electrons per shell					
			1	2	3	4	5	6
Aluminum	13	Al	2	8	3			
Antimony	51	Sb	2	8	18	18	5	
Arsenic	33	As	2	8	18	5		
Barium	56	Ba	2	8	18	18	8	2
Beryllium	4	Be	2	2				
Boron	5	B	2	3				
Cadmium	48	Cd	2	8	18	18	2	
Carbon	6	C	2	4				
Chlorine	17	Cl	2	8	7			
Cobalt	27	Co	2	8	15	2		
Copper	29	Cu	2	8	18	1		
Gallium	31	Ga	2	8	18	3		
Germanium	32	Ge	2	8	18	4		
Gold	79	Au	2	8	18	32	18	1
Helium	2	He	2					
Hydrogen	1	H	1					
Indium	49	In	2	8	18	18	3	
Iodine	53	I	2	8	18	18	7	

Electron Shells (Continued)

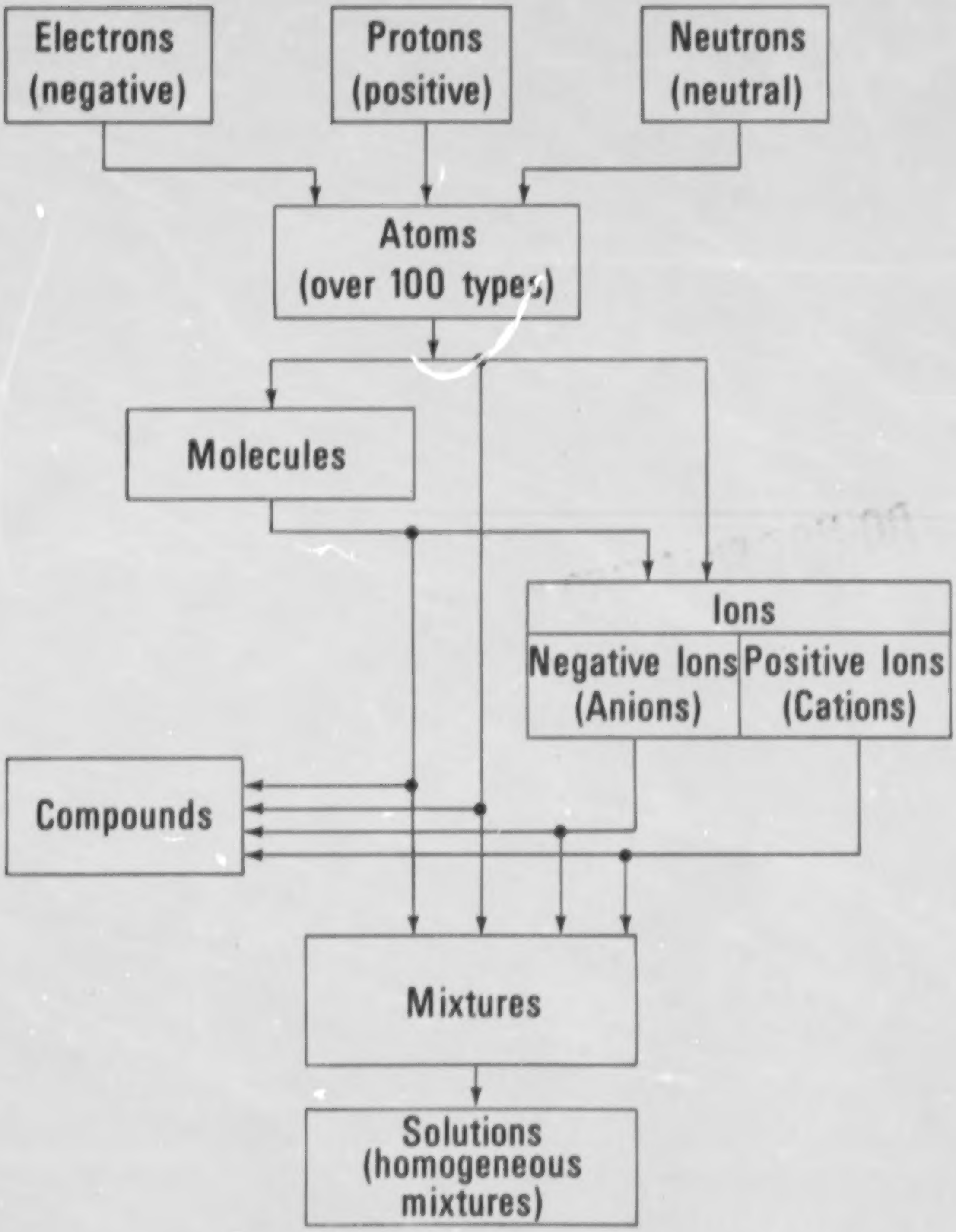
Element	Atomic No.	Symbol	Electrons per shell					
			1	2	3	4	5	6
Iridium	77	Ir	2	8	18	32	15	2
Lead	82	Pb	2	8	18	32	18	4
Lithium	3	Li	2	1				
Mercury	80	Hg	2	8	18	32	18	2
Neon	10	Ne	2	8				
Nitrogen	7	N	2	5				
Oxygen	8	0	2	6				
Phosphorus	15	P	2	8	5			
Radon	86	Rn	2	8	18	32	18	8
Selenium	34	Se	2	8	18	6		
Silicon	14	Si	2	8	4			
Silver	47	Ag	2	8	18	18	1	
Sodium	11	Na	2	8	1			
Sulfur	16	S	2	8	6			
Tantalum	73	Ta	2	8	18	32	11	2
Tin	50	Sn	2	8	18	18	4	
Titanium	22	Ti	2	8	10	2		
Zinc	30	Zn	2	8	18	2		

Parts of the Atom


Valence Ring
Electrons
Nucleus
1. Protons
2. Neutrons

(Note: The representation illustrated is a beryllium atom which has four protons, four electrons, and five neutrons.)

Building Blocks of Matter



Electrons
(negative)
Protons
(positive)
Neutrons
(neutral)
Atoms
(over 100 types)
Molecules
Ions
Negative Ions
(Anions)
Positive Ions
(Cations)
Compounds
Mixtures
Solutions
(homogeneous
mixtures)

ATOMS AND MATERIALS
UNIT I

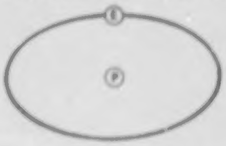
ASSIGNMENT SHEET #1--MAKE SKETCHES OF SIMPLE ATOMS

NAME____ SCORE______________

It is important to understand the structure of the atom in order to understand the effects of electricity, magnetism, and heat. Sketch structures of the simple atoms described below as illustrated in Figure 1. Have your instructor check your work.

EXAMPLE: The hydrogen atom normally has one electron, one proton, and no neutrons; the particles are identified by an "E" for electron, and a "P" for proton

FIGURE 1



A. The helium atom has two electrons, two protons, and two neutrons. Make a sketch of the helium atom in the space below. Use "E" to indicate electrons, "P" for protons, and "N" for neutrons

B. The lithium atom has three electrons, three protons, and one neutron. Make a sketch of the lithium atom in the space below

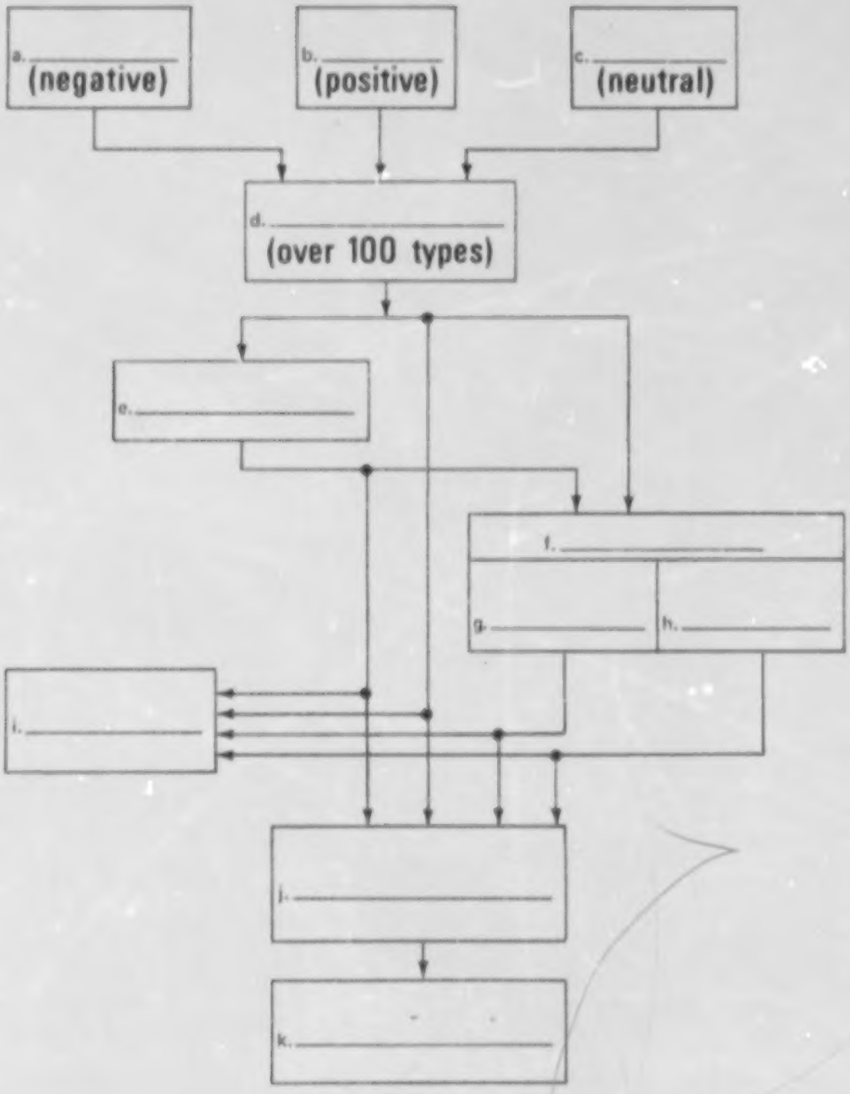
ATOMS AND MATERIALS
UNIT I

ASSIGNMENT SHEET #2--IDENTIFY THE BUILDING BLOCKS OF MATTER

NAME____ SCORE____________

The structure of matter is important in understanding batteries, transistors, rectifiers, and vapor lamps. Identify the blocks in Figure 2 by placing their correct names in the spaces provided. Do not refer to any other material until you have completed the diagram. Have your instructor check your work.

FIGURE 2

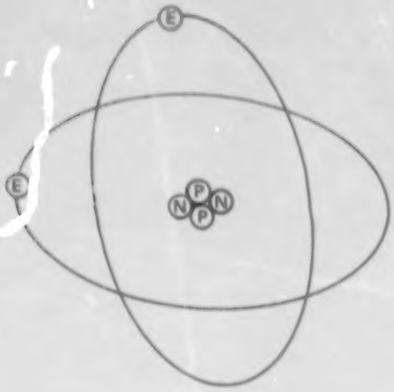

a. __________ (negative)
b. __________ (positive)
c. __________ (neutral)
d. __________ (over 100 types)
e. __________
f. __________
g. __________
h. __________
i. __________
j. __________
k. __________

ATOMS AND MATERIALS
UNIT I

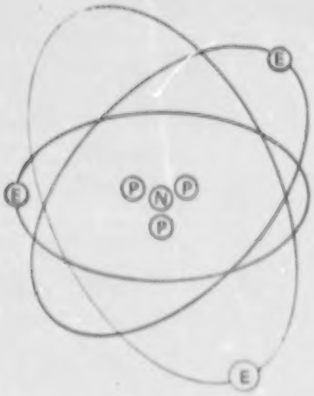
ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A.



B.



Assignment Sheet #2

a. Electrons

b. Protons

c. Neutrons

d. Atoms

e. Molecules

f. Ions

g. Negative ions

h. Positive ions

i. Compounds

j. Mixtures

k. Solutions

ATOMS AND MATERIALS
UNIT I

JOB SHEET #1--MEASURE CONDUCTION AND OBSERVE CHANGES

I. Equipment and materials

- A. Glass or plastic container--Clean 250 ml-1000 ml (1/2 pt-1 qt) with wide mouth or open top containing no more than 250 ml (1/2 pint) of clean tap water
- B. Table salt--Approximately 55 gm (2 oz)
- C. Ohmmeter--With leads previously adjusted and checked by instructor
- D. Stirring rod or stick

II. Procedure

- A. Turn on the ohmmeter as directed by your instructor
- B. Place leads no more than 1.25 cm (1/2 in.) into water at opposite sides of container
- C. Record reading on ohmmeter dial in the space provided under "Job Sheet Results"

  NOTE: Ask instructor for assistance if necessary
- D. Add pinch of salt
- E. Stir
- F. Record ohmmeter reading
- G. Repeat steps D, E, and F until readings remain about the same, or your salt quantity is exhausted, or you have fifteen readings recorded under "Job Sheet Results."

  (NOTE: Show results to instructor.)
- H. Empty container
- I. Clean equipment and work area
- J. Put equipment and materials away

JOB SHEET #1

III. Job sheet results

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________
11. ______________________________
12. ______________________________
13. ______________________________
14. ______________________________
15. ______________________________

ATOMS AND MATERIALS
UNIT I

TEST

NAME____ SCORE__________

1. Match terms associated with atoms and materials to their correct definitions. Write the correct numbers in the blanks.

______a. One of over 100 basic materials, each made of a distinct atom; combines to form substances, mixtures, and compounds

______b. Neutrally-charged, subatomic particle found in the nucleus of atoms

______c. Electrical charge of the proton; attracts electrons

______d. Homogenous mixture

______e. Foreign material that enters into an otherwise relatively pure substance

______f. Condition or state of having excess or insufficient number of electrons; causes the atom or molecule to be negative or positive

______g. Smallest particle of an element; particles that bind together to form molecules

______h. Electrical charge of the electron; attracts protons

______i. Spherical surface formed around the atom nucleus by electron orbits at distinct distances from the nucleus

______j. Atom or molecule that has an excess or insufficient number of electrons and, thus, is electrically unbalanced or charged

______k. Core of the atom composed of protons and neutrons around which electrons orbit

______l. Made of substances that mix perfectly and blend together so that they are not individually observable in the mixture

1. Atom
2. Charge
3. Element
4. Impurity
5. Negative
6. Neutron
7. Positive
8. Solution
9. Ion
10. Homogeneous
11. Nucleus
12. Shell

TEST

______m. Negatively-charged, subatomic particle that orbits around the nucleus of an atom and can be separated from atoms to flow as electricity

______n. Substance made of two or more elements atomically bonded together

______o. Linking together of two or more atoms to form molecules

______p. Atoms or molecules that have lost electrons, causing them to have a positive charge; also called *cations*

______q. Material in which atoms and molecules are rigidly held in a distinct orderly arrangement

______r. Smallest particle of a compound; made of two or more identical or different atoms

______s. Compound of oxygen atoms and other atoms

______t. Positively-charged, subatomic particle found in the atom's nucleus

______u. The outermost shell of the atom

______v. Electrons whose orbits are contained in the outer shell

______w. Atoms or molecules having extra electrons, causing them to have a negative charge; also called *anions*

13. Proton
14. Compound
15. Negative ions
16. Crystal
17. Positive ions
18. Molecule
19. Atomic bonding
20. Electron
21. Valence ring
22. Valence electrons
23. Oxide

2. Match terms associated with electrical circuitry to their correct definitions. Write the correct numbers in the blanks.

______a. Substance used on large electrical connections to aid flow of electricity across connection

______b. Flowing of electrons

______c. Electronic device made of semiconductor material that amplifies electrical signals

______d. Material that is not a good conductor or a good insulator but will conduct variously under different conditions

1. Transistor
2. Electricity
3. Contact paste
4. Semiconductor

TEST

______e. Electricity flowing through an unintentional path

______f. Alloy of soft metals, usually tin and lead, used to fuse electrical conductors

______g. Occurrence of electrical sparks; visible electrical flashes

______h. Result of metal reacting with other elements and producing scale, film, and deterioration

______i. Substance used to improve soldering process; acts as a chemical metal cleaner and aids in heat conduction during soldering; also known as *solder paste*

______j. Device made of semiconductor material; used in electronic equipment

______k. Material restricting electron flow

______l. Area of connectors or terminals that mates to other connectors or terminals through which electricity passes

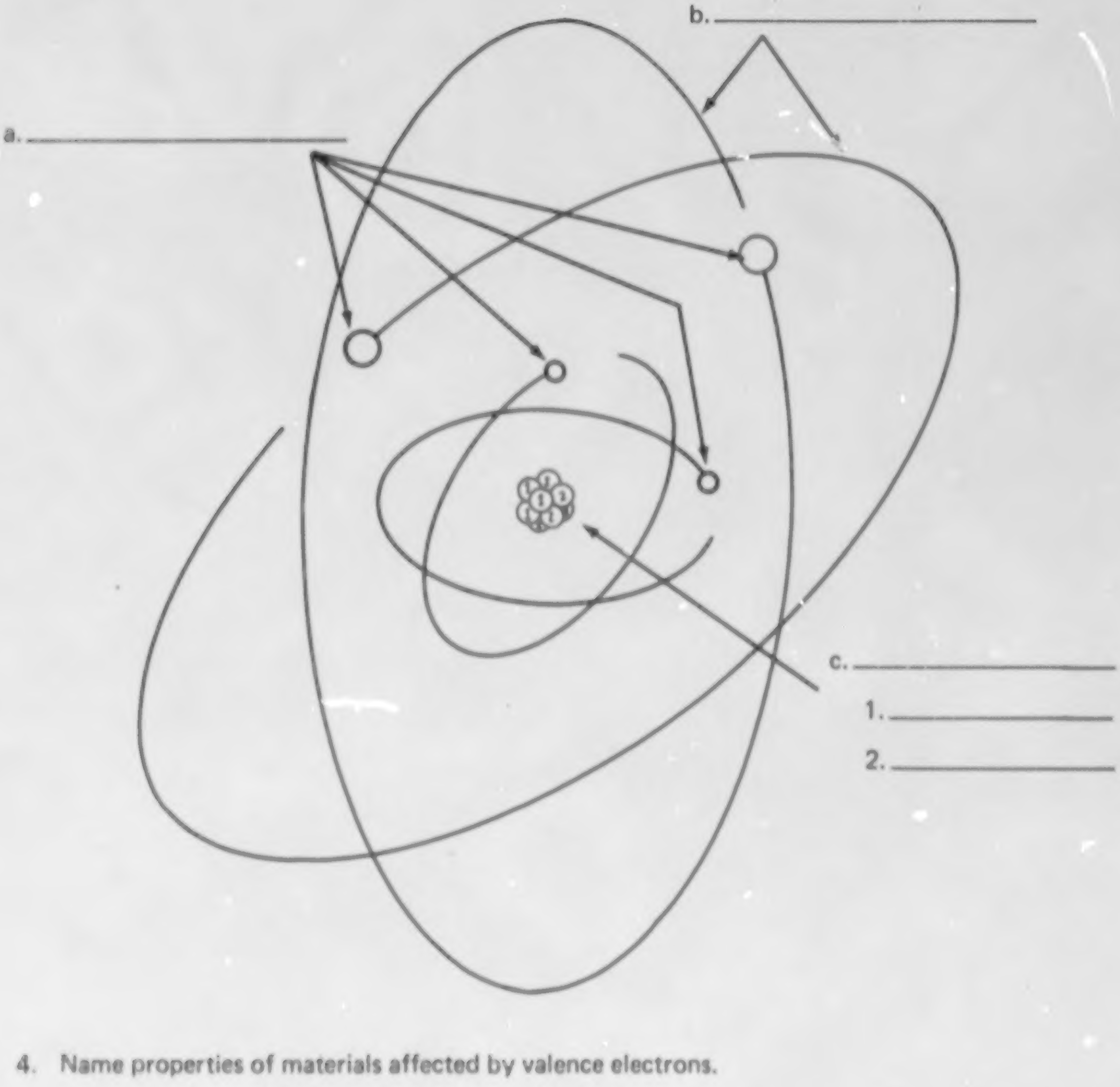
______m. Material through which electrons flow easily

______n. Measurement of material's ability to allow electron flow

5. Electrical short circuit
6. Insulator
7. Flux
8. Conductivity
9. Conductor
10. Arcing
11. Corrosion
12. Contact area
13. Solid-state diode
14. Solder

TEST

3. Identify parts of the atom. Write the correct name of each part in the appropriate blanks.



4. Name properties of materials affected by valence electrons.

a. ____

b. ____

c. ____

TEST

5. Match the building blocks of matter to their correct descriptions. Write the numbers in the correct blanks.

_____a. Formed by the combinations of atoms and molecules of different elements

_____b. Formed by homogeneous mixtures

_____c. Formed by combining atoms of the same element or of different elements

_____d. Result of elements, compounds, or substances mixed together without losing their individual characteristics

_____e. Result of atoms or molecules either gaining or losing electrons to become charged

_____f. Made of electrons, protons, and neutrons combined in various proportions to form over 100 types which constitute the elements

_____g. Negatively-charged; have extra electrons

_____h. Positively-charged; are short of electrons

1. Atoms
2. Molecules
3. Ions
4. Compounds
5. Mixtures
6. Solutions
7. Positive ions
8. Negative ions

6. Discuss the relationship between valence electrons and conductivity in conductors, semiconductors, and insulators.

a. Conductors-- ______________________________

____

____

____

b. Semiconductors-- ______________________________

____

____

____

c. Insulators-- ______________________________

____

____

____

TEST

7. Describe the effects of heat on conductors, semiconductors, and insulators.

   a. Conductors-- ____

   ____

   ____

   b. Semiconductors-- ____

   ____

   ____

   c. Insulators-- ____

   ____

   ____

8. Describe the effects of impurities on conductors, semiconductors, and insulators.

   a. Conductors-- ____

   ____

   ____

   b. Semiconductors-- ____

   ____

   ____

   c. Insulators-- ____

   ____

   ____

9. Classify kinds of conductors, semiconductors, and insulators. Write a "C" for conductors, an "S" for semiconductors, and an "I" for insulators.

   _____a. Silicon

   _____b. Cadmium

   _____c. Nylon

   _____d. Oil

   _____e. Gold

TEST

_____f. Copper

_____g. Selenium

_____h. Carbon

_____i. Silver

_____j. Aluminum

_____k. Bakelite

_____l. Germanium

_____m. Vinyl

_____n. Mercury

_____o. Mica

_____p. Porcelain

10. Match methods of preventing corrosion to their correct results. Write the correct numbers in the blanks.

_____a. Aids in electrical conduction across the connection; seals air from metal surfaces

_____b. Replaces corrosive air with noncorrosive gas

_____c. Keeps out corrosive elements by using weatherproof enclosures for outdoor use, waterproof enclosures in damp and humid places, and completely sealed enclosures in areas with oil, fumes, smoke, or dust

_____d. Reduces heat that aids corrosion; eliminates foreign material between contacts which can cause corrosion

_____e. Makes better connections; eliminates corrosive effects of acids and chemicals intended for nonelectrical soldering

_____f. Eliminates corrosion caused by joining different metals without using special connector

_____g. Prevents loose connectors which generate heat, thus aiding corrosion; prevents electricai arcing between loose connectors which causes rapid corrosion of metals

1. Cleaning contact areas before assembly
2. Tightening connections
3. Using contact paste
4. Using correct solder and flux
5. Using correct connectors
6. Maintaining sealed enclosures of special gases
7. Using correct electrical equipment enclosures

TEST

(NOTE: Test questions 11, 12, and 13 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

11. Make sketches of simple atoms.

12. Identify the building blocks of matter.

13. Demonstrate the ability to measure conduction and observe changes.

ATOMS AND MATERIALS
UNIT I

ANSWERS TO TEST

1. a. 3
   b. 6
   c. 7
   d. 8
   e. 4
   f. 2
   g. 1
   h. 5
   i. 12
   j. 9
   k. 11
   l. 10
   m. 20
   n. 14
   o. 19
   p. 17
   q. 16
   r. 18
   s. 23
   t. 13
   u. 21
   v. 22
   w. 15

2. a. 3
   b. 2
   c. 1
   d. 4
   e. 5
   f. 14
   g. 10
   h. 11
   i. 7
   j. 13
   k. 6
   l. 12
   m. 9
   n. 8

3. a. Electrons
   b. Valence ring
   c. Nucleus
      1. Protons
      2. Neutrons

ANSWERS TO TEST

4. a. Electrical conductivity

   b. Atomic bonding

   c. Molecular structure

5. a. 4

   b. 6

   c. 2

   d. 5

   e. 3

   f. 1

   g. 8

   h. 7

6. Discussion should include:

   a. Conductors--Valence electrons are loosely attached to the atom and easily separate to flow as electricity

   b. Semiconductors-Valence electrons are more strongly attached to the atom and will separate only if enough voltage is applied

   c. Insulators--Valence electrons are very strongly attached to the atom and require applying tremendous force to become separated

7. Description should include:

   a. Conductors--Heat increases resistance by causing loosely assembled metal atoms to vibrate violently and disrupt the usually unimpaired electron flow

   b. Semiconductors--Heat decreases resistance by causing strongly attached electrons to become separated more eaily from the atom

   c. Insulators--Moderate amounts of heat have little effect on good insulators; however, prolonged exposure to heat will cause many insulating materials to harden, become brittle, crack, peel, and often become semiconductors

8. Description should include:

   a. Conductors--Decrease conductivity due to disruption in the normal flow of electrons; also impurities combine with conductor atoms and help secure electrons into molecules where they are not as easily separated

   b. Semiconductors--Aid the flow of electrons and transform these into conductors

   c. Insulators--Assist the flow of electrons and transform these into semiconductors

ANSWERS TO TEST

9. a. S
   b. C
   c. I
   d. I
   e. C
   f. C
   g. S
   h. S
   i. C
   j. C
   k. I
   l. S
   m. I
   n. C
   o. I
   p. I
10. a. 3
   b. 6
   c. 7
   d. 1
   e. 4
   f. 5
   g. 2
11. Evaluated to satisfaction of instructor
12. Evaluated to satisfaction of instructor
13. Performance skills evaluated to satisfaction of instructor

MAGNETISM
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to determine the direction of the magnetic field around a conductor, determine the north and south poles of an electromagnet, and measure relay coil current requirements. This knowledge will be shown by completing assignment sheets, job sheet, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with magnetism to their correct definitions.
2. Name electrical devices utilizing magnetism.
3. Identify the direction of magnetic lines of flux.
4. State the left-hand rule for electromagnets.
5. Distinguish between magnetic and nonmagnetic metals.
6. Discuss the differences between the structure of magnetic and nonmagnetic materials.
7. Name methods of increasing the strength of an electromagnet.
8. Distinguish between permanent and temporary magnetic material.
9. Define hysteresis.
10. Identify parts of a hysteresis curve.
11. Determine magnetic polarity of electromagnets.
12. Determine the direction of current flow and the magnetic field of a conductor.
13. Demonstrate the ability to measure relay coil electrical current requirements.

MAGNETISM
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheets.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Use TM #6 and TM #7 to explain the hysteresis plot.

   H. Show electrical equipment having magnets such as motors and relays.

   I. Set up a hand-wound electromagnet and demonstrate the methods of increasing its strength as discussed in Objective B.

   J. If time permits, have students make their own electromagnets using metal rods or bolts as cores.

   K. Demonstrate magnetic attraction and repulsion.

   L. Explain circuits used in the job sheet.

   M. Give test.

II. Instructional materials

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM #1--Left-hand Rule for Magnetic Lines of Flux

      2. TM #2--Left-hand Rule for Electromagnets

      3. TM #3--Magnetic Material

      4. TM #4--Nonmagnetic Material

      5. TM #5--Strengthening an Electromagnet

SUGGESTED ACTIVITIES

6. TM #6--Hysteresis Curve

7. TM #7--Electromagnet for Testing Hysteresis

D. Assignment sheets

1. Assignment Sheet #1--Identify the Parts of a Hysteresis Curve

2. Assignment Sheet #2--Determine Magnetic Polarity of Electromagnets

3. Assignment Sheet #3--Determine the Direction of Current Flow and the Magnetic Field of a Conductor

E. Answers to assignment sheets

F. Job Sheet #1--Measure Relay Coil Electrical Current Requirements

G. Test

H. Answers to test

III. Unit references

A. Halliday, David, and Robert Resnick. *Fundamentals of Physics*. New York: John Wiley & Sons, Inc., 1970.

B. Van Vlack, Lawrence H. *Materials Science for Engineers*. Reading, Massachusetts: Addison-Wesley Publishing Company, 1970.

MAGNETISM
UNIT II

INFORMATION SHEET

I. Terms and definitions

   A. Electromagnet--Magnet created by flow of electricity through coils of wire

   B. North pole--End of magnet which would point toward the earth's South Pole; end from which magnetic lines of force are considered to be exiting

   C. South pole--End of magnet which would point toward the earth's North Pole; end into which magnetic lines of force are considered to be entering

   D. Molecular structure--Form of the natural pattern, ties, and bonds that holds matter together

   E. Polar--Having two distinct ends, each with a different electrical or magnetic property

   F. Alloy--Metal material made by mixing two or more metals

   G. Toroid--Shaped like a ring or doughnut

   H. Magnetism--Invisible force that results from electrons in motion

   I. Natural magnet--Material found in nature which has the quality to attract other materials

   J. Synthetic magnet--Magnets that are produced by magnetizing a piece of iron or steel

   K. Temporary magnet--Magnet produced by passing a current through a coil surrounding a piece of iron or steel; continues only while current is flowing

   L. Retentivity--Ability of material to retain magnetism

   M. Residual magnetism--Magnetism remaining in material after charging force has been removed

   N. Reluctance--Resistance of a magnetic path to the flow of magnetic lines of force

   O. Magnetic field--Area where magnetic force can be detected around a magnet; also called *magnetic flux*

   P. Hysteresis curve--Curve showing the magnetic effect of increasing and decreasing force

INFORMATION SHEET

II. Electrical devices utilizing magnetism

  A. Electric motor

  B. Electric generator or alternator

  C. Relay

  D. Solenoid

  E. Transformer

  F. Computer memory system

  G. Tape recorder

  H. Electrical meters

  I. Speakers

III. Direction of magnetic lines of flux (Transparency #1; Figures 1-4)

  A. Electron in motion

FIGURE 1

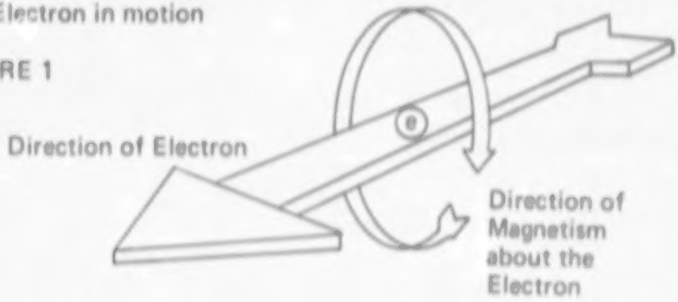
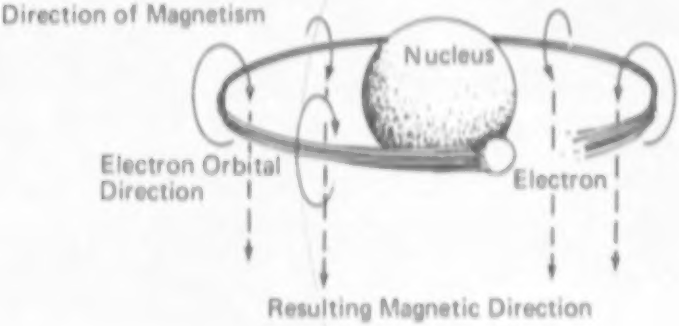

Direction of Electron
e
Direction of Magnetism about the Electron

FIGURE 2

  B. Electron in orbit around the nucleus of the atom

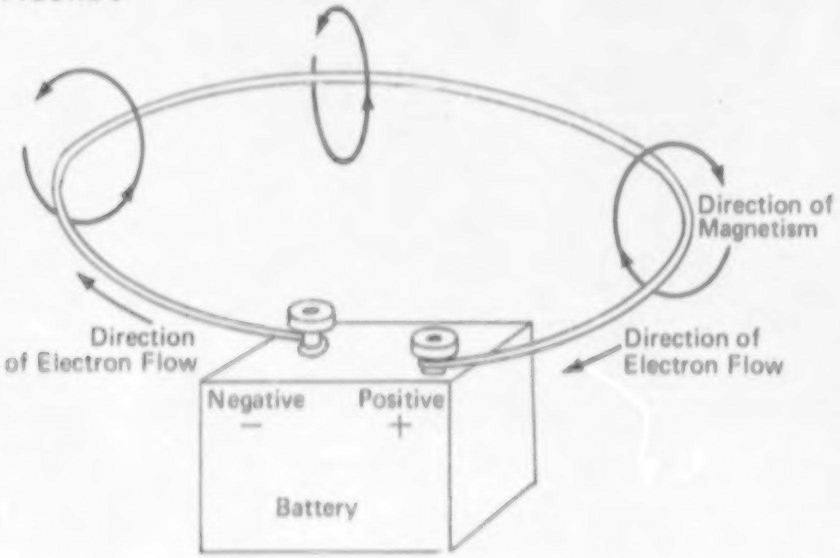

Direction of Magnetism
Nucleus
Electron Orbital Direction
Electron
Resulting Magnetic Direction

INFORMATION SHEET

C. Electrons in a conductor

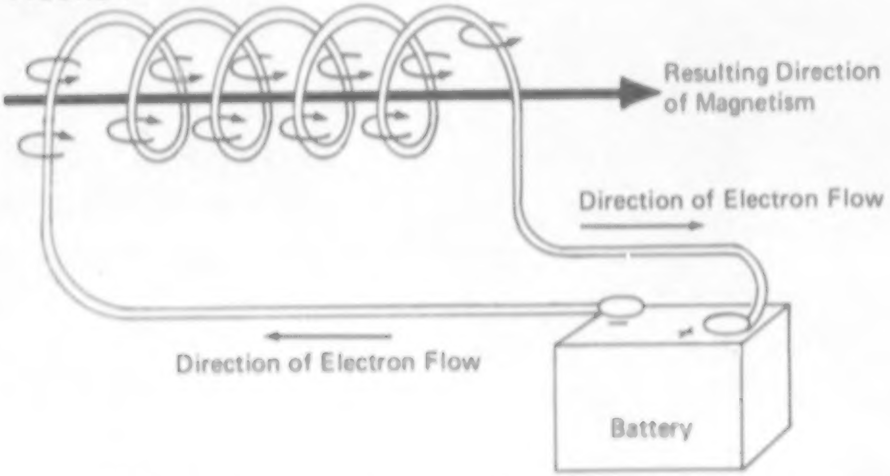
(NOTE: *Electricity* is electrons flowing in a conductor.)

FIGURE 3


Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Negative
−
Positive
+
Battery

D. Electron flow in a coil or wire or "electromagnet"

FIGURE 4


Resulting Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
−
+
Battery

(NOTE: To distinguish between the two ends of magnets, the end represented by the arrowhead above is called the *north pole* and the other end is called the *south pole*.)

INFORMATION SHEET

IV. Left-hand rule for electromagnets (Transparency #2)--If a coil of wire is held in the LEFT hand, the fingers curled around the coils point in the direction of electron flow, and the extended thumb points in the direction of magnetism, which is called the *north pole*

V. Magnetic and nonmagnetic metals

- A. Magnetic
  1. Iron
  2. Tin
  3. Carbon steel
  4. Molten aluminum
- B. Nonmagnetic
  1. Copper
  2. Brass
  3. Aluminum
  4. Stainless steel

VI. Structure of magnetic and nonmagnetic materials

- A. Magnetic materials--Groups of atoms that act as tiny magnets and can move to alignment in one general direction; the net effect is magnetism (Transparency #3)
- B. Nonmagnetic materials (Transparency #4)
  1. Groups of atoms that act as tiny magnets are restricted by their molecular structures from moving into alignment; the net effect is no magnetism
  2. Individual atoms or groups of atoms which have no magnetic polarity at all

VII. Methods of increasing the strength of an electromagnet (Transparency #5)

- A. Increase flow of electricity through coils
- B. Increase number of turns of coil
- C. Add type of magnetic core material
- D. Increase diameter of coil

INFORMATION SHEET

VIII. Permanent and temporary magnetic material

- A. Permanent magnetic material
  1. Made from certain steel alloys
  2. Magnetized with difficulty
  3. Retains magnetism well

  EXAMPLES OF USES: DC motors, ignition systems, tachometers

- B. Temporary magnetic material
  1. Made from soft iron and iron alloys
  2. Magnetized easily
  3. Loses magnetism quickly

  EXAMPLES OF USES: Relay coils, transformer cores, AC motor field coils

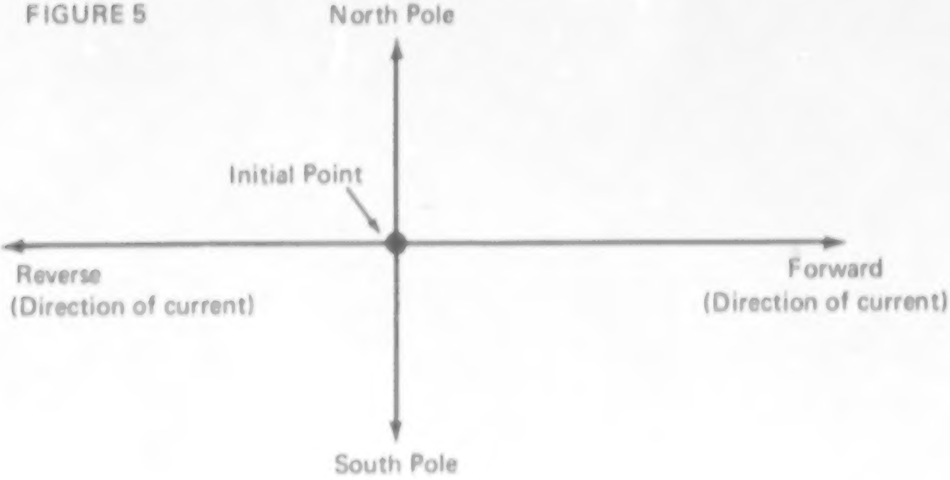
IX. Hysteresis--Tendency of magnetic material to not only resist being magnetized and resist having the magnetic direction reversed, but also to retain magnetism

X. Parts of a hysteresis curve (Transparencies #6 and #7)

- A. Initial point (Figure 5)

  (NOTE: This point on the plot shows that with no electric current, there will be no magnetism in the material because it is assumed to have not been previously magnetized.)

FIGURE 5

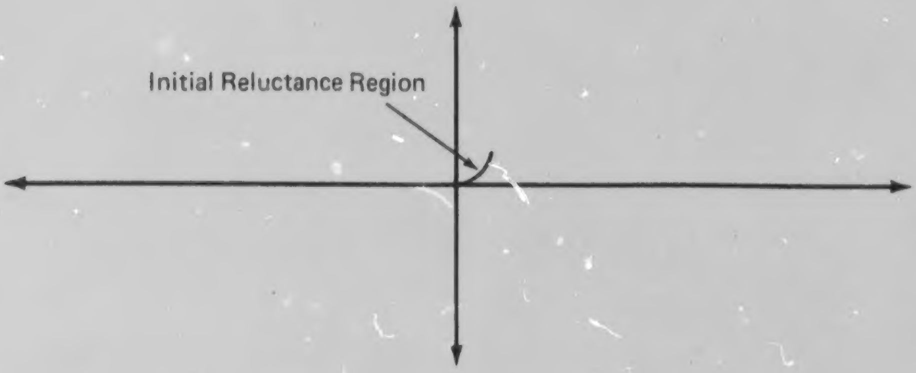

North Pole
Initial Point
Reverse
(Direction of current)
Forward
(Direction of current)
South Pole

INFORMATION SHEET

B. Initial reluctance region (Figure 6)

(NOTE: This region shows that initially the material is slow to magnetize.)

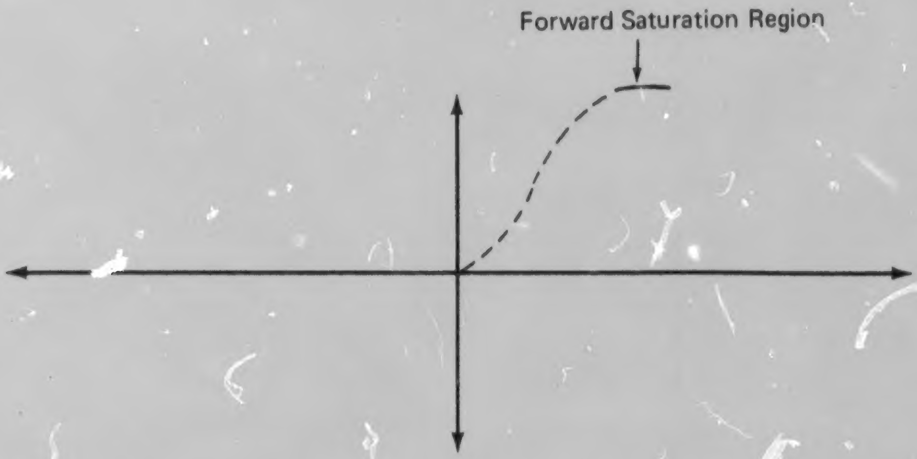
FIGURE 6


Initial Reluctance Region

C. Forward saturation region (Figure 7)

(NOTE: This region shows that the material will accept only a limited amount of magnetism, regardless of increased electrical current.)

FIGURE 7

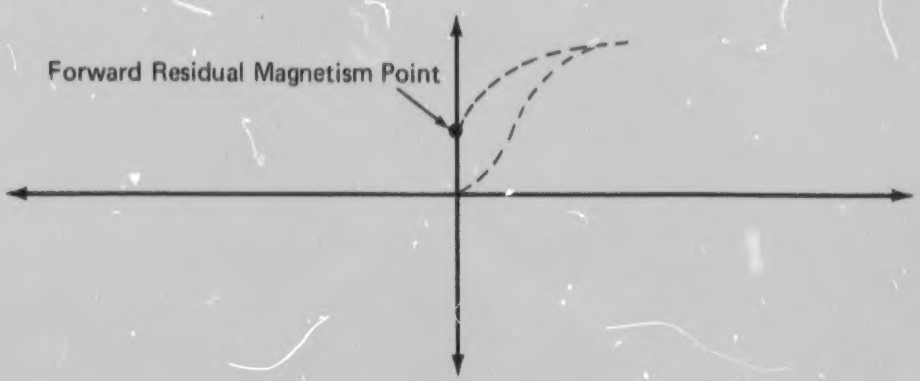

Forward Saturation Region

INFORMATION SHEET

D. Forward residual magnetism point (Figure 8)

(NOTE: This point shows that after the electrical current is returned to zero, the material will still have some magnetism of its own.)

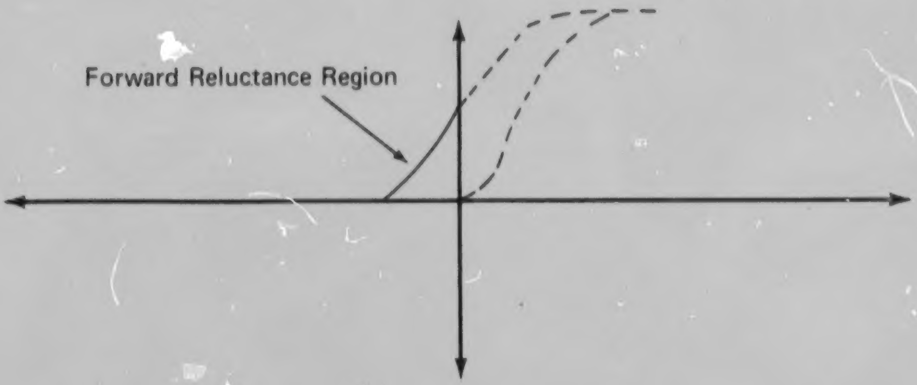
FIGURE 8


Forward Residual Magnetism Point

E. Forward region of reluctance to changing of magnetic direction (Figure 9)

(NOTE: This region shows that even after electric current is flowing in the opposite direction, the material is still magnetized in its previous direction.)

FIGURE 9

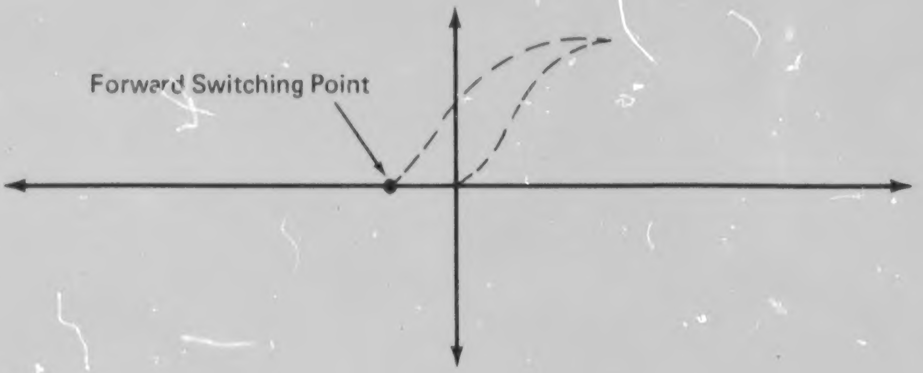

Forward Reluctance Region

INFORMATION SHEET

F. Forward switching point (Figure 10)

(NOTE: At this point, material is switching to the opposite direction.)

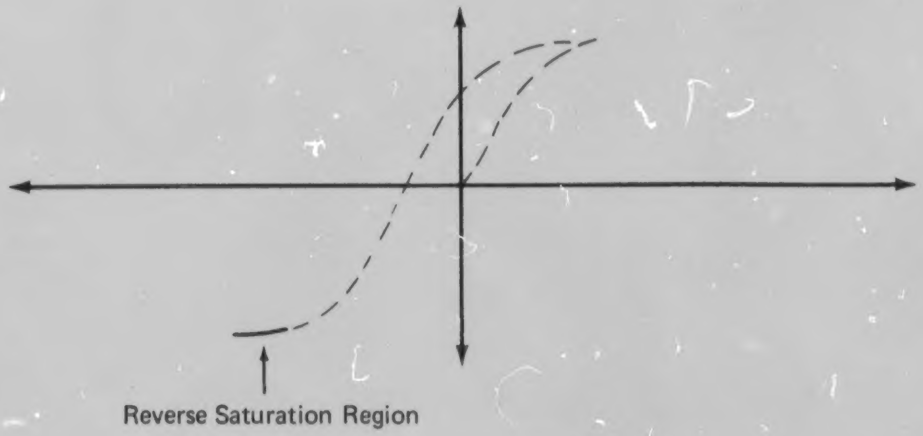
FIGURE 10


Forward Switching Point

G. Reverse saturation region (Figure 11)

(NOTE: This region shows that material will saturate in either direction.)

FIGURE 11

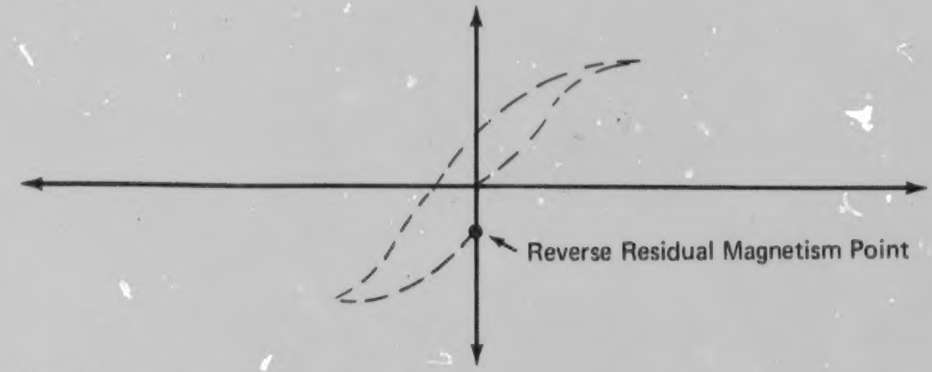

Reverse Saturation Region

INFORMATION SHEET

H. Reverse residual magnetism point (Figure 12)

(NOTE: This point shows that if electric current is again brought to zero, the material will still maintain some residual magnetism; however, now it is in the opposite direction.)

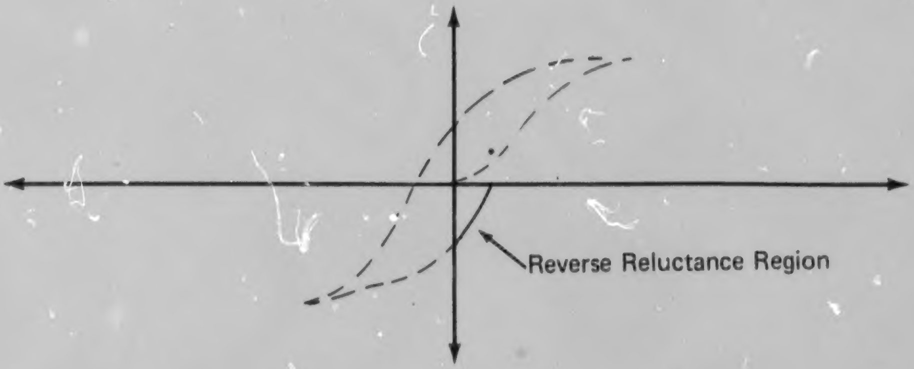
FIGURE 12


Reverse Residual Magnetism Point

I. Reverse region of reluctance to changing of magnetic direction (Figure 13)

(NOTE: This region shows that even after electric current is flowing in the opposite direction, the material is still magnetized in its previous direction.)

FIGURE 13

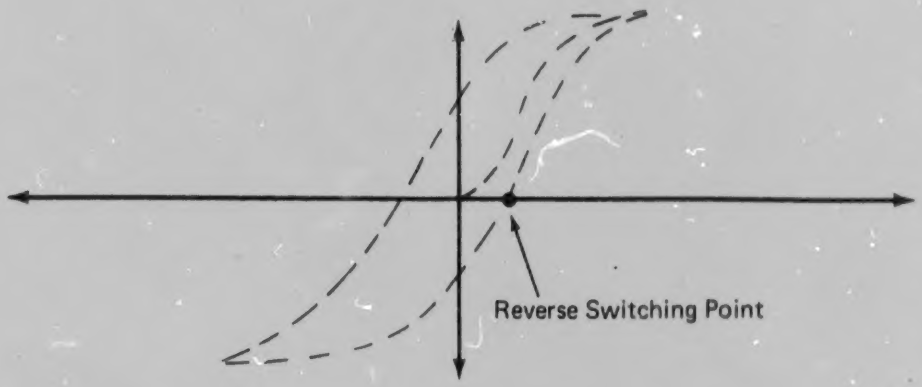

Reverse Reluctance Region

INFORMATION SHEET

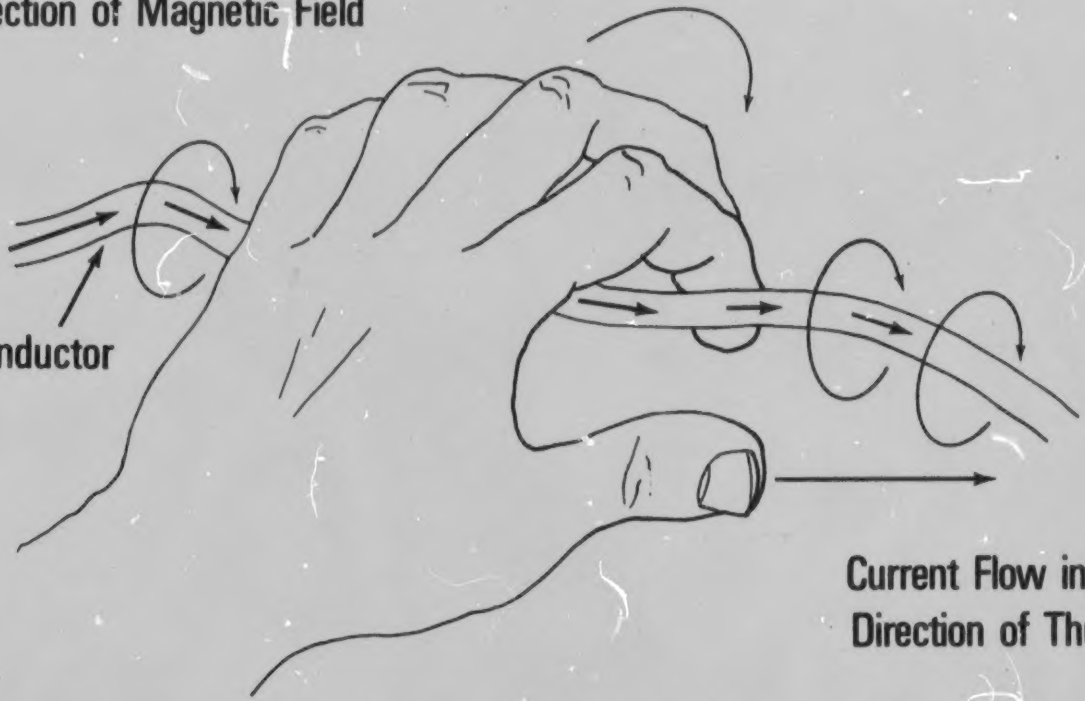
J. Reverse switching point (Figure 14)

(NOTE: At this point, material is switching to the opposite direction.)

FIGURE 14


Reverse Switching Point

Left-Hand Rule for Magnetic Lines of Flux



Fingers Around Conductor Indicate
Direction of Magnetic Field

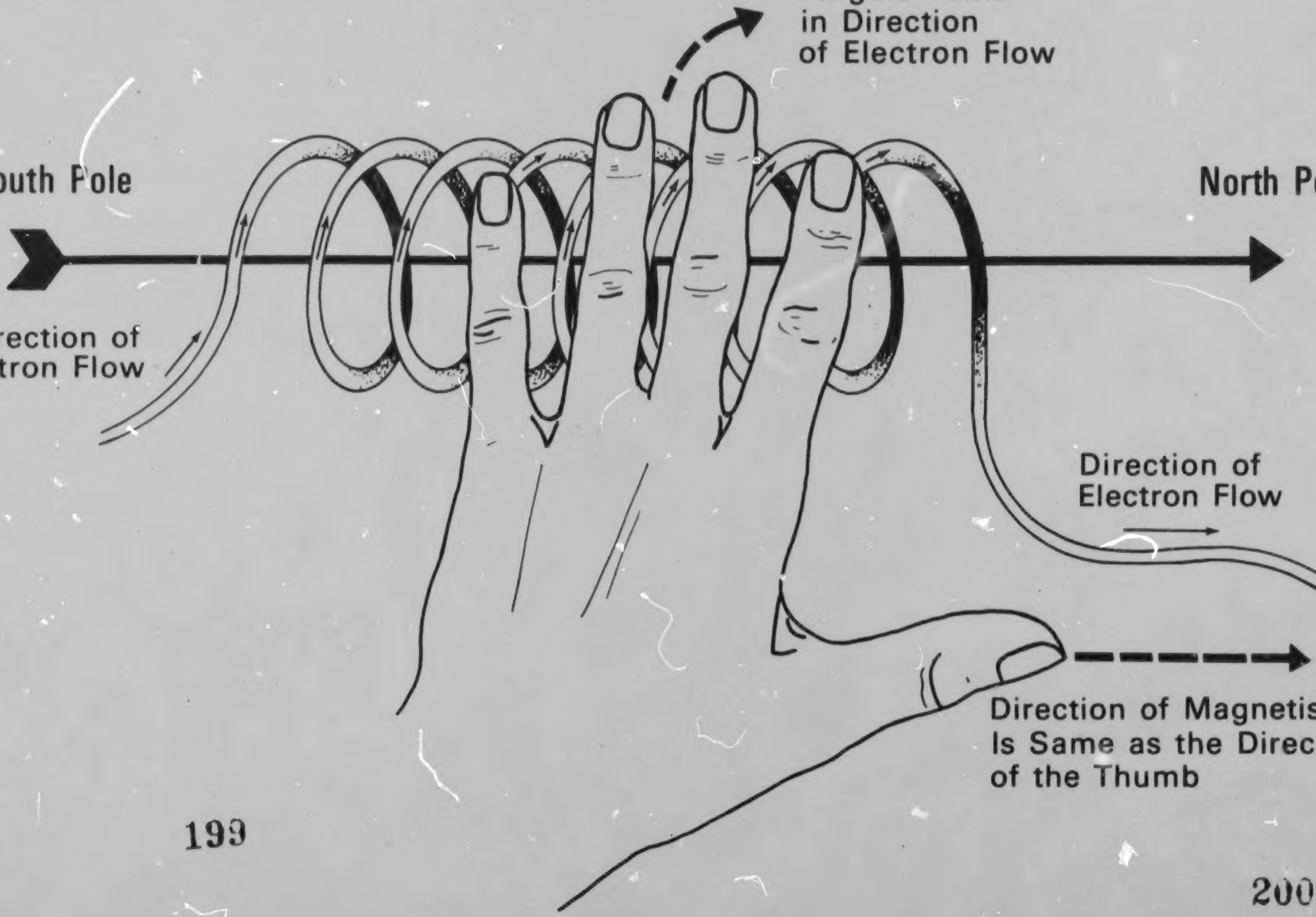
Conductor

Current Flow in
Direction of Thumb

TM #1

IIEE - 55-B

Left-Hand Rule for Electromagnets



Fingers Point
in Direction
of Electron Flow

South Pole

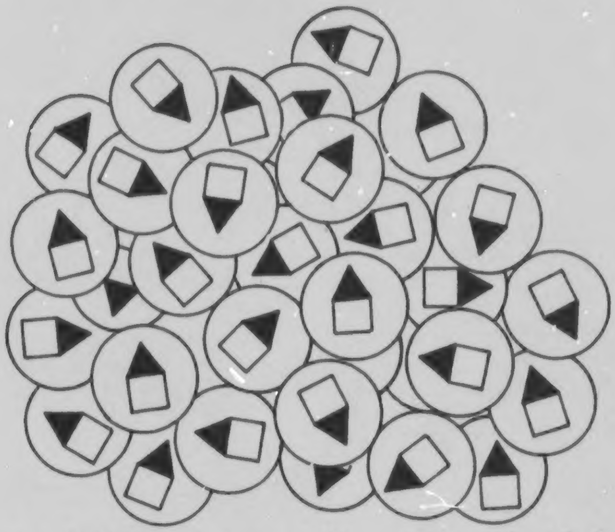
North Pole

Direction of
Electron Flow

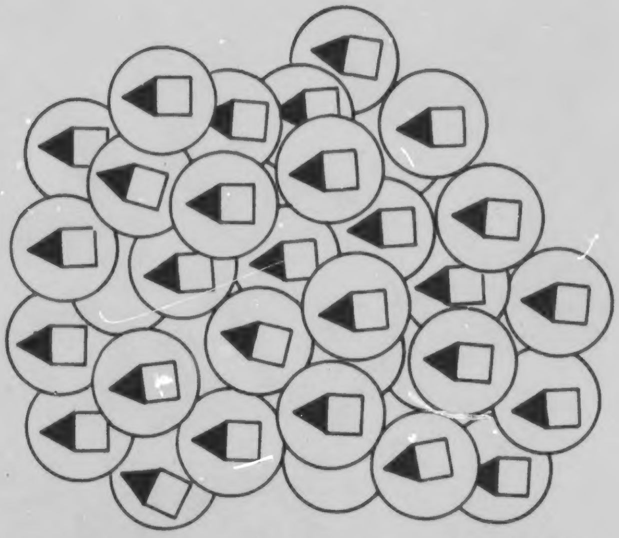
Direction of
Electron Flow

Direction of Magnetism
Is Same as the Direction
of the Thumb

Magnetic Material

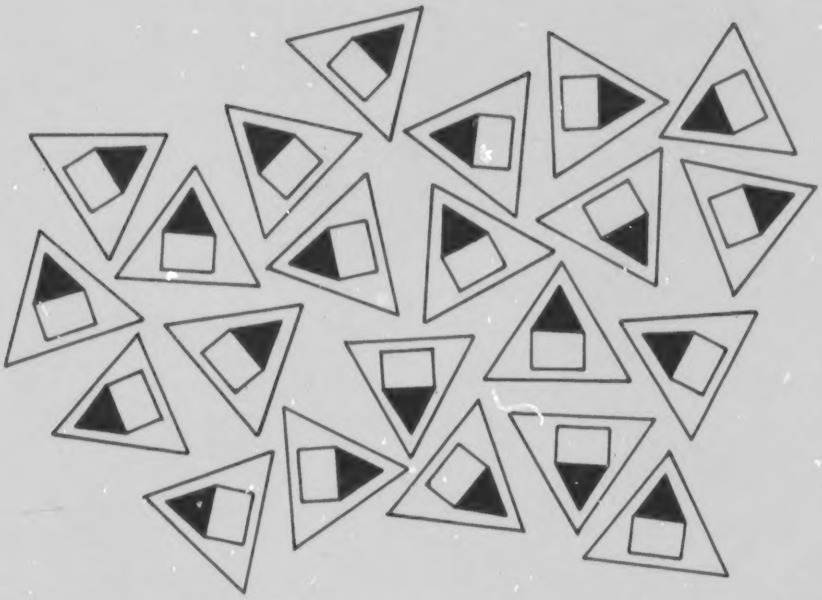


Groups of Atoms in an Unmagnetized Material
Are Randomly Directed

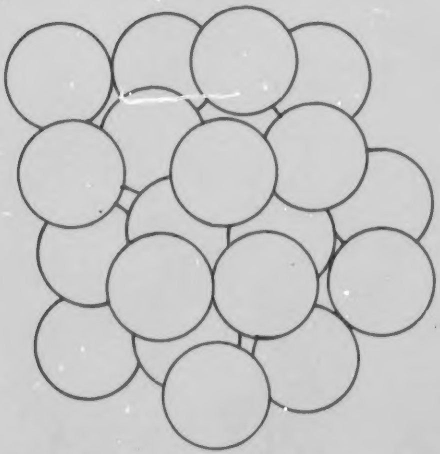


Groups of Atoms in a Magnetized Material
Are Generally Aligned

Nonmagnetic Material

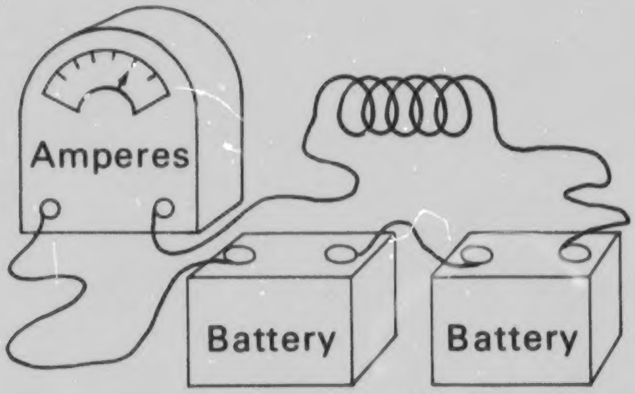


Tiny Magnetic Groups of Atoms Are Restricted from Alignment by Their Molecular Structure

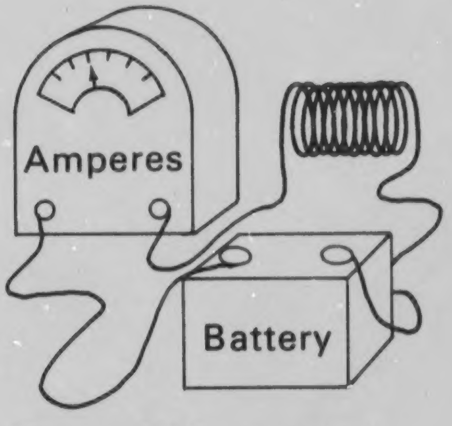


Atoms or Groups of Atoms Having No Magnetic Polarity Cannot Be Magnetized

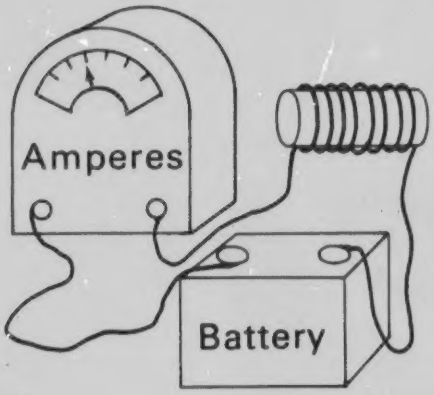
Strengthening an Electromagnet


Amperes
Battery
Battery

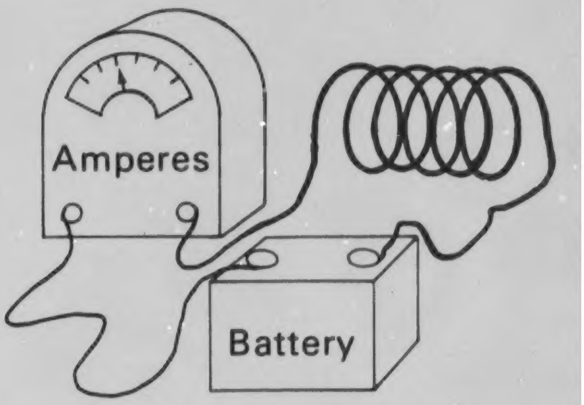
Stronger Electromagnet
with More Electrical Current


Amperes
Battery

Stronger Electromagnet
with More Coils

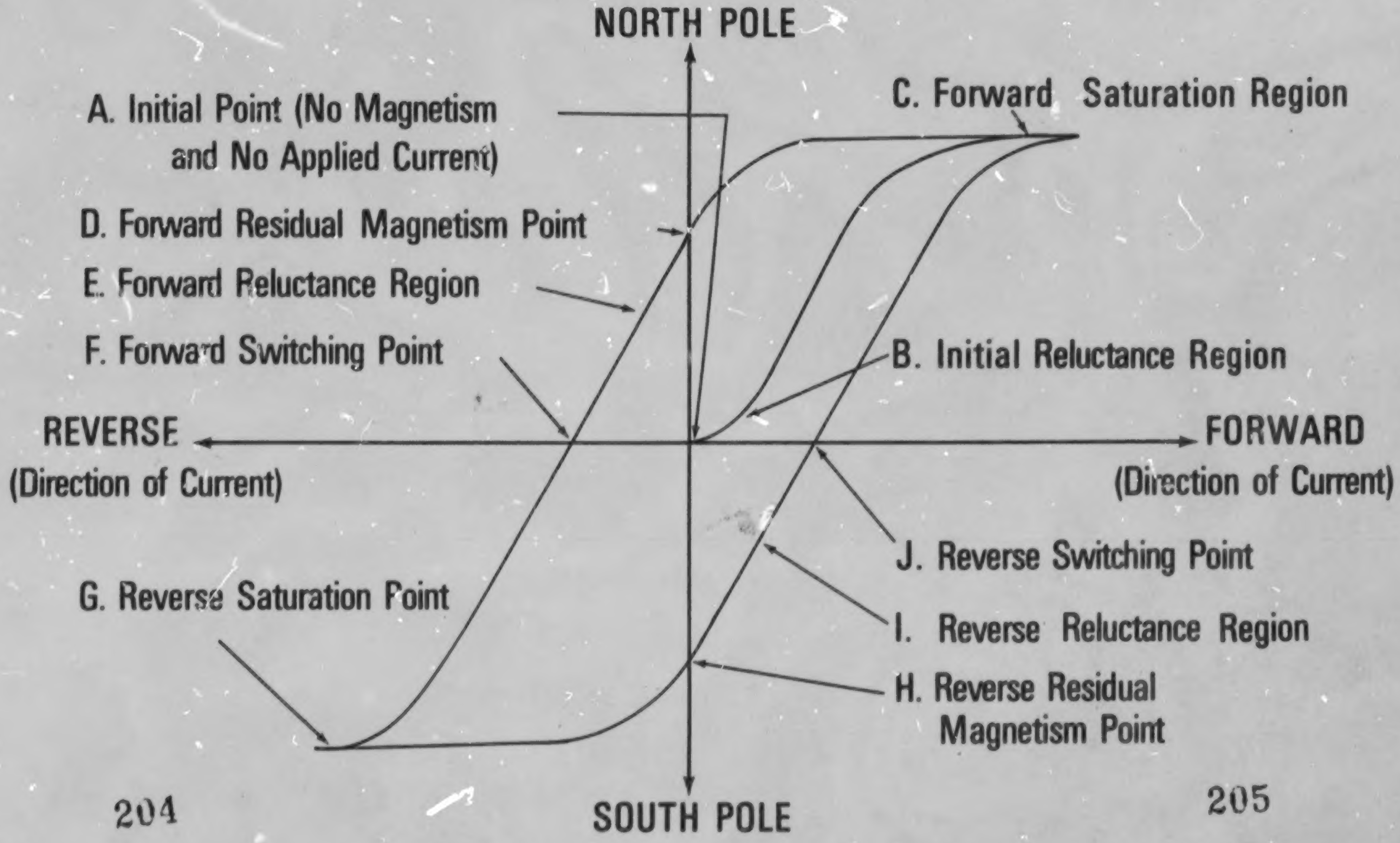

Amperes
Battery

Stronger Electromagnet
with Iron Core


Amperes
Battery

Stronger Electromagnet
with Increased
Diameter of Coils

Hysteresis Curve



NORTH POLE

A. Initial Point (No Magnetism and No Applied Current)

B. Initial Reluctance Region

C. Forward Saturation Region

D. Forward Residual Magnetism Point

E. Forward Reluctance Region

F. Forward Switching Point

G. Reverse Saturation Point

H. Reverse Residual Magnetism Point

I. Reverse Reluctance Region

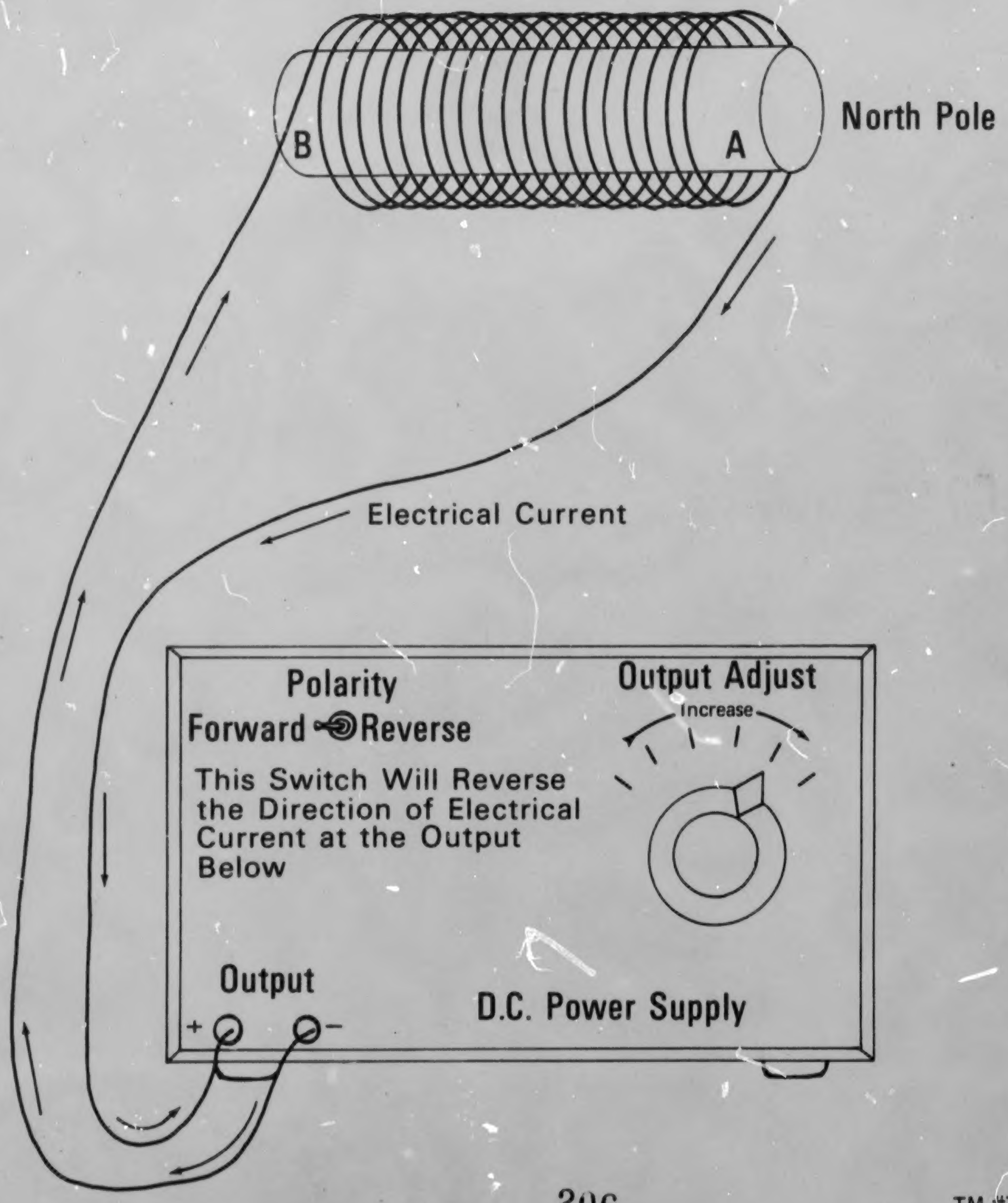
J. Reverse Switching Point

REVERSE (Direction of Current)

FORWARD (Direction of Current)

SOUTH POLE

Electromagnet for Testing Hysteresis


North Pole
B
A
Electrical Current
Polarity
Forward
Reverse
This Switch Will Reverse the Direction of Electrical Current at the Output Below
Output Adjust
Increase
Output
+
−
D.C. Power Supply

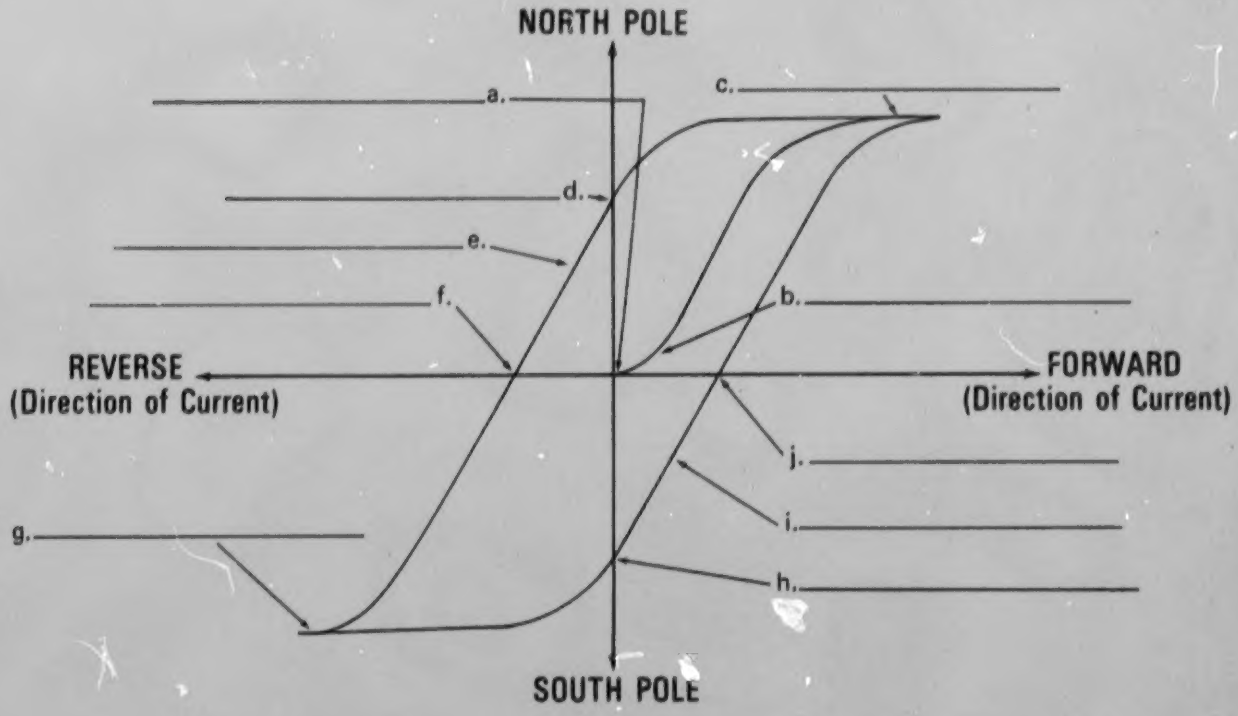
MAGNETISM
UNIT II

ASSIGNMENT SHEET #1--IDENTIFY THE PARTS OF A HYSTERESIS CURVE

NAME____ SCORE______________

Identify the parts of a hysteresis curve in Figure 15. Write the correct names in the blanks.

FIGURE 15


NORTH POLE
a. ____________________
c. ____________________
d. ____________________
e. ____________________
f. ____________________
b. ____________________
REVERSE
(Direction of Current)
FORWARD
(Direction of Current)
j. ____________________
i. ____________________
g. ____________________
h. ____________________
SOUTH POLE

MAGNETISM
UNIT II

ASSIGNMENT SHEET #2--DETERMINE MAGNETIC POLARITY OF ELECTROMAGNETS

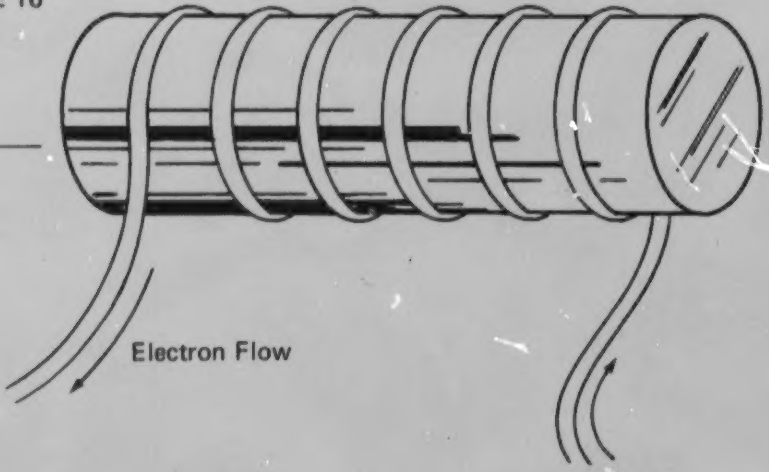
NAME________________________________ SCORE____________________

Electromagnets are an essential part of electric motors, relays, solenoids, and other electrical devices. In these devices, electrical currents and coil windings may be in either direction. In each problem below (Figures 16-19), determine the north and south poles of the electromagnets, and place your answer on the line provided. Check with your instructor when you have completed this assignment.

1.

FIGURE 16

a.________

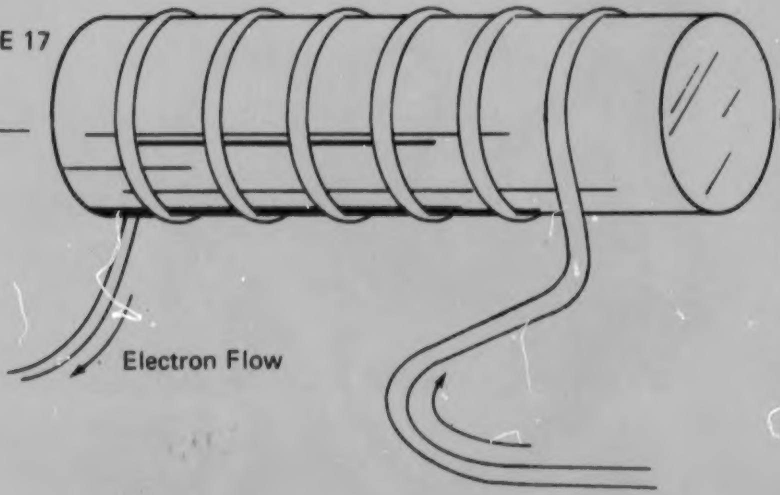


b.________

2.

FIGURE 17

a.________

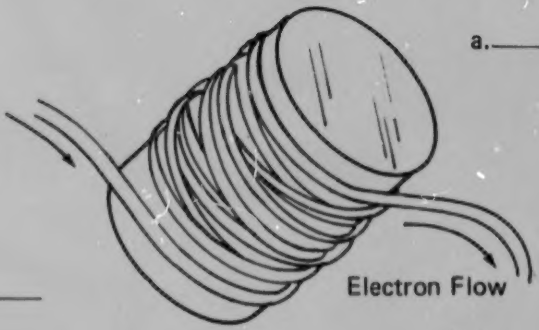


b.________

ASSIGNMENT SHEET #2

3.

FIGURE 18

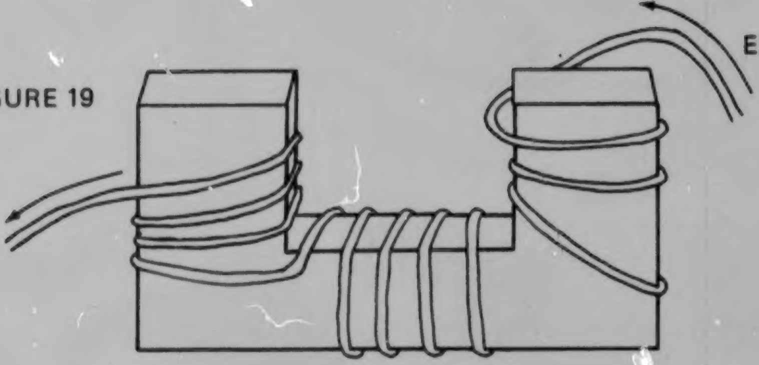

Electron Flow

a.________________

b.________________

4.

FIGURE 19


Electron Flow

b.________________

a.________________

9

MAGNETISM
UNIT II

ASSIGNMENT SHEET #3--DETERMINE THE DIRECTION OF CURRENT FLOW AND THE MAGNETIC FIELD OF A CONDUCTOR

NAME______________________ SCORE______________

In Figures 20 and 21 below, determine the direction of current flow and the magnetic field of a conductor. Draw in the appropriate arrows where needed to show the flow and field.

FIGURE 20

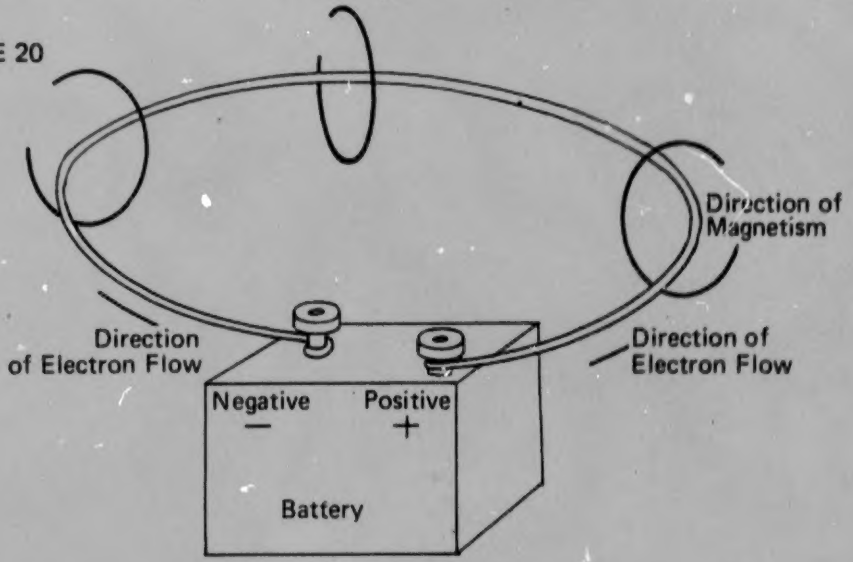
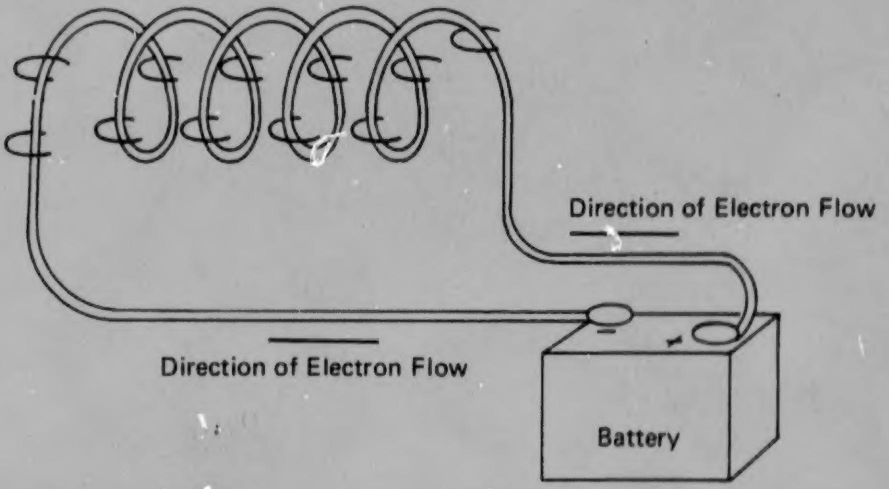

Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Negative
—
Positive
+
Battery

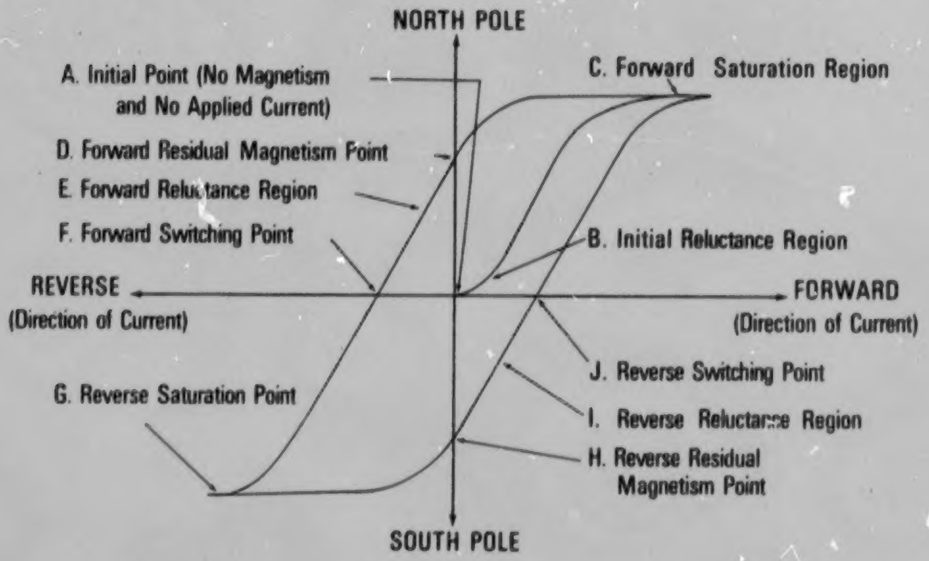
FIGURE 21


Direction of Electron Flow
Direction of Electron Flow
–
+
Battery

MAGNETISM
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

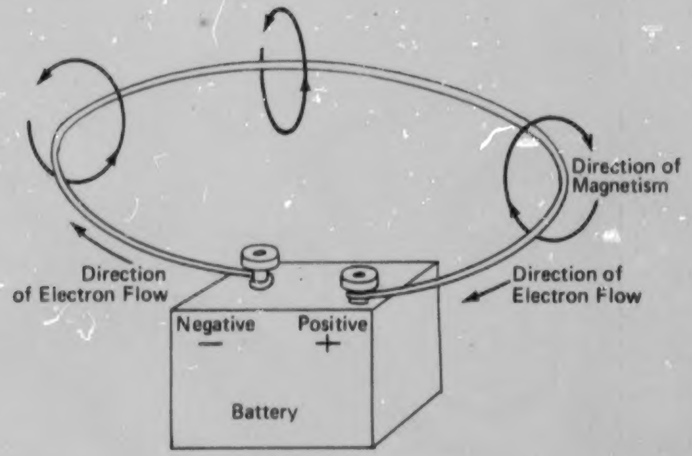

NORTH POLE
A. Initial Point (No Magnetism and No Applied Current)
C. Forward Saturation Region
D. Forward Residual Magnetism Point
E. Forward Reluctance Region
F. Forward Switching Point
B. Initial Reluctance Region
REVERSE (Direction of Current)
FORWARD (Direction of Current)
J. Reverse Switching Point
G. Reverse Saturation Point
I. Reverse Reluctance Region
H. Reverse Residual Magnetism Point
SOUTH POLE

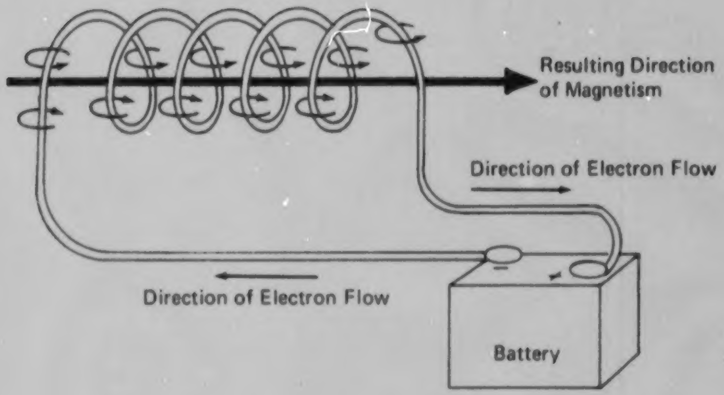
Assignment Sheet #2

1. a. North
   b. South
2. a. South
   b. North
3. a. South
   b. North
4. a. North
   b. South

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #3


Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Negative
−
Positive
+
Battery


Resulting Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Battery

MAGNETISM
UNIT II

JOB SHEET #1--MEASURE RELAY COIL ELECTRICAL CURRENT REQUIREMENTS

I. Equipment and materials

A. Variable power supply--AC or DC, depending on the relay listed below

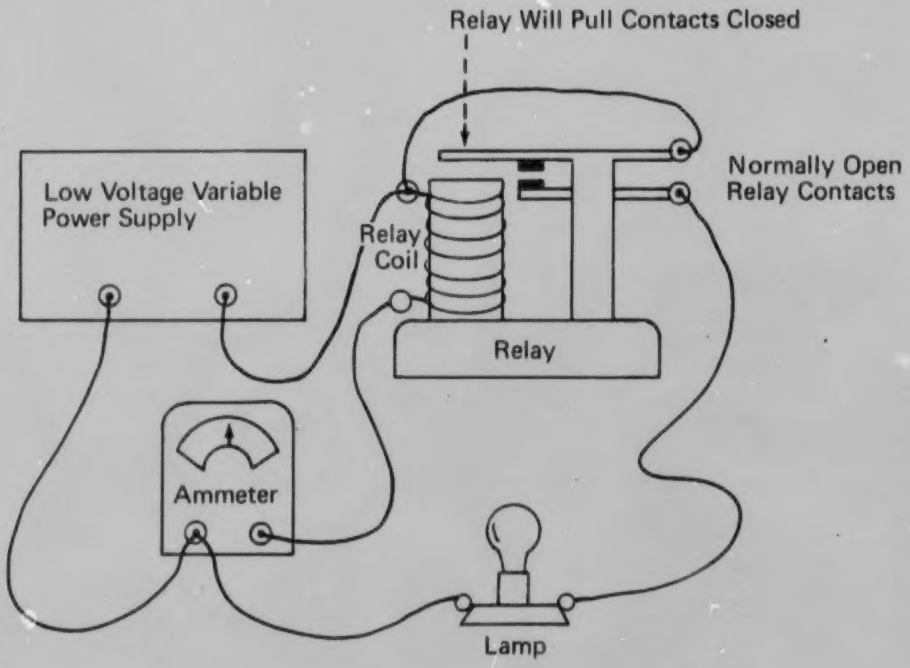
B. Relay--Low voltage AC or DC, with at least one set of "Normally Open" (NO) contacts

C. Ammeter--AC or DC, depending upon the relay listed above, with measuring range appropriate for the relay

D. Lamp--Low voltage near that of the relay rating

E. Test leads--6 each, 30 to 60 cm (12 to 24 in.) in length

FIGURE 22


Relay Will Pull Contacts Closed
Normally Open Relay Contacts
Low Voltage Variable Power Supply
Relay Coil
Relay
Ammeter
Lamp

JOB SHEET #1

II. Procedure

A. Assemble the equipment as shown in Figure 22

B. Disconnect one of the leads from the power supply

C. Turn power supply on

D. Verify that output is turned to zero or the lowest level

E. Turn power supply off

F. Reconnect test lead

G. Turn power supply on

H. Increase output voltage very slowly while watching ammeter indication increase

I. Stop increasing power supply the moment lamp turns on

J. Record the ammeter reading in the space provided

K. Decrease power supply until the lamp goes off

L. Record this ammeter reading in the space provided

M. Repeat steps H through L two more times

N. Make recordings of ammeter readings below

(NOTE: Is the same amount of electrical current required to activate the relay as the amount of electrical current required to hold the relay in once it is activated? If not, why? Show your results to the instructor, and have your instructor explain any significant differences.)

O. Put equipment and materials away

III. Results

	A. Ammeter readings when lamp goes on	B. Ammeter readings when lamp goes off
First measurements	1. ______________	2. ______________
Second measurements	2. ______________	2. ______________
Third measurements	3. ______________	3. ______________

MAGNETISM
UNIT II

TEST

NAME______________________________ SCORE__________________________

1. Match terms associated with magnetism with their correct definitions. Write the correct numbers in the blanks.

______a. Metal material made by mixing two or more metals

______b. End of magnet which would point toward earth's North Pole; end into which magnetic lines of force are considered to be entering

______c. Magnet created by flow of electricity through coils of wire

______d. Shaped like a ring or doughnut

______e. Form of the natural pattern, ties, and bonds that holds matter together

______f. Having two distinct ends, each with a different electrical or magnetic property

______g. Invisible force that results from electrons in motion

______h. End of magnet which would point toward the earth's South Pole; end from which magnetic lines of force are considered to be exiting

______i. Magnet produced by passing a current through a coil surrounding a piece of iron or steel; continues only while current is flowing

______j. Area where magnetic force can be detected around a magnet; also called *magnetic flux*

______k. Resistance of a magnetic path to the flow of magnetic lines of force

______l. Material found in nature which has the quality to attract other materials

______m. Ability of material to retain magnetism

______n. Curve showing the magnetic effect of increasing and decreasing magnetizing force

1. Electromagnet
2. North Pole
3. South Pole
4. Molecular structure
5. Polar
6. Alloy
7. Toroid
8. Magnetism
9. Natural magnet
10. Synthetic magnet
11. Temporary magnet
12. Retentivity
13. Residual magnetism
14. Reluctance
15. Magnetic field
16. Hysteresis curve

TEST

_____o. Magnetism remaining in material after charging force has been removed

_____p. Magnets that are produced by magnetizing a piece of iron or steel

2. Name seven electrical devices utilizing magnetism.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

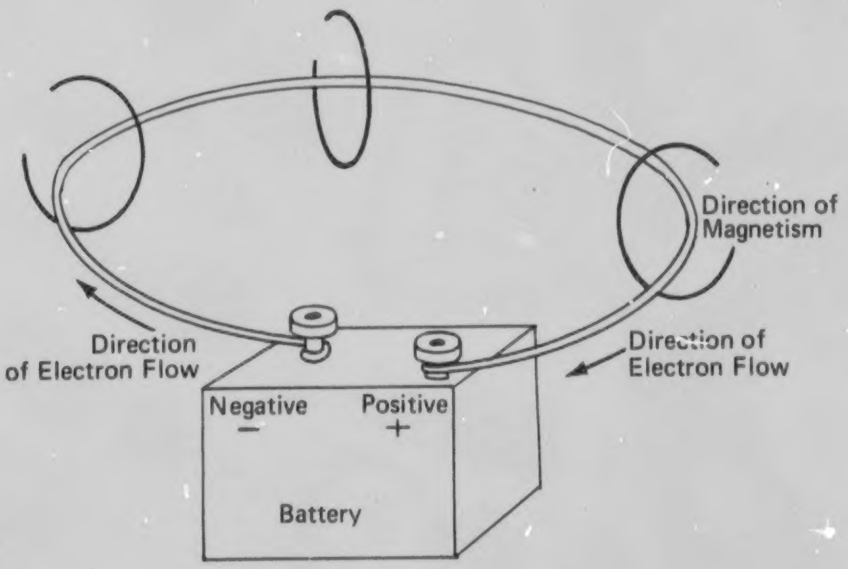
e. ______________________________

f. ______________________________

g. ______________________________

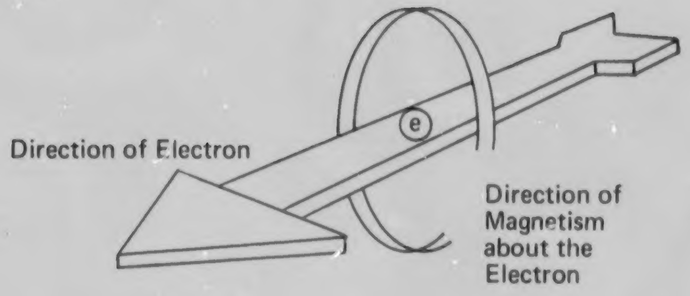
3. Identify the direction of magnetic lines of flux by completing the drawings below.

a.

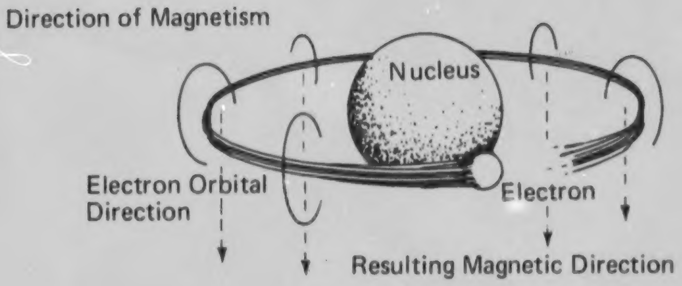

Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Negative
−
Positive
+
Battery

TEST

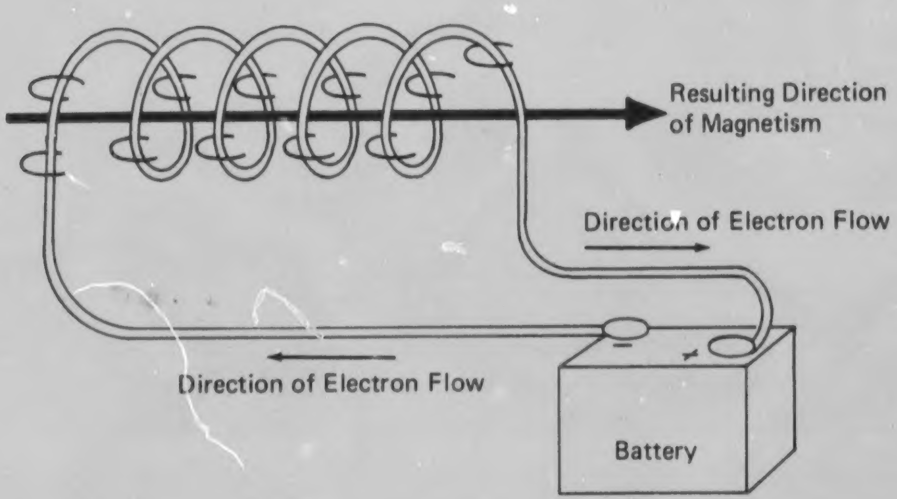
b.


Direction of Electron
e
Direction of Magnetism about the Electron

c.


Direction of Magnetism
Nucleus
Electron Orbital Direction
Electron
Resulting Magnetic Direction

d.


Resulting Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Battery
–
+

TEST

4. State the left-hand rule for electromagnets.

____

____

____

____

5. Distinguish between magnetic and nonmagnetic metals. Write an "M" for magnetic metals, and an "NM" for nonmagnetic metals.

_____a. Copper

_____b. Molten aluminum

_____c. Carbon steel

_____d. Brass

_____e. Iron

_____f. Aluminum

_____g. Stainless steel

_____h. Tin

6. Discuss in a short paragraph the differences between the structure of magnetic and nonmagnetic materials.

____

____

____

____

____

____

____

____

____

7. Name methods of increasing the strength of an electromagnet.

____

____

TEST

8. Distinguish between permanent and temporary magnetic material. Write a "P" for permanent magnetic material, and a "T" for temporary magnetic material.

_____a. Magnetized with difficulty

_____b. Made from soft iron and iron alloys

_____c. Retains magnetism well

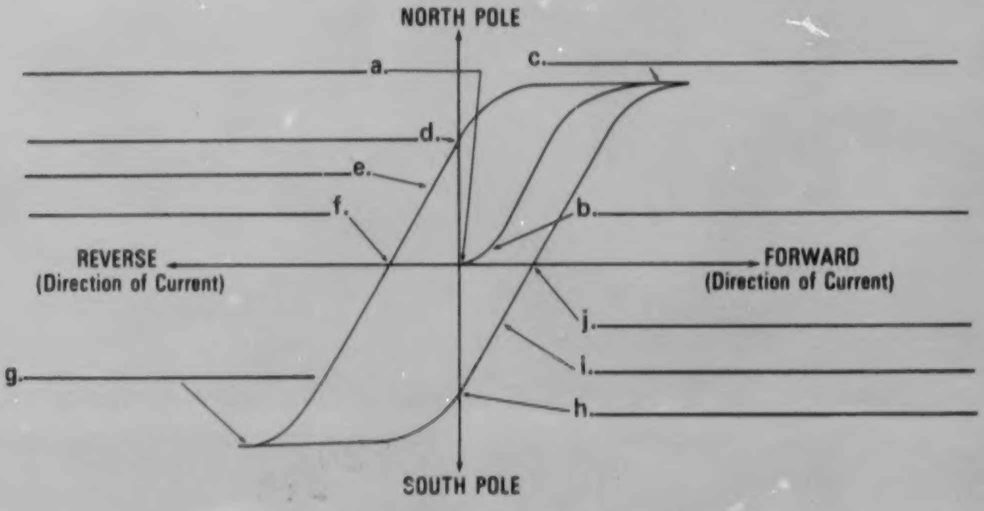
_____d. Loses magnetism quickly

_____e. Magnetized easily

_____f. Made from certain steel alloys

9. Define hysteresis.

10. Identify parts of a hysteresis plot in the diagram below.


NORTH POLE
a.
c.
d.
e.
f.
b.
REVERSE (Direction of Current)
FORWARD (Direction of Current)
j.
i.
g.
h.
SOUTH POLE

TEST

(NOTE: Test questions 11-14 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

11. Identify parts of a hysteresis curve.

12. Determine magnetic polarity of electromagnets.

13. Determine the direction of current flow and magnetic field of a conductor.

14. Demonstrate the ability to measure relay coil electrical current requirements.

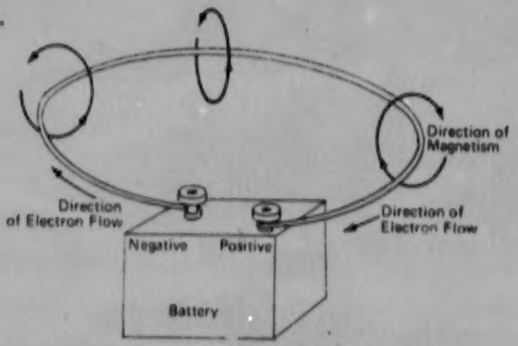
MAGNETISM
UNIT II

ANSWERS TO TEST

1. a. 6
   b. 3
   c. 1
   d. 7
   e. 4
   f. 5
   g. 8
   h. 2
   i. 11
   j. 15
   k. 14
   l. 9
   m. 12
   n. 16
   o. 13
   p. 10

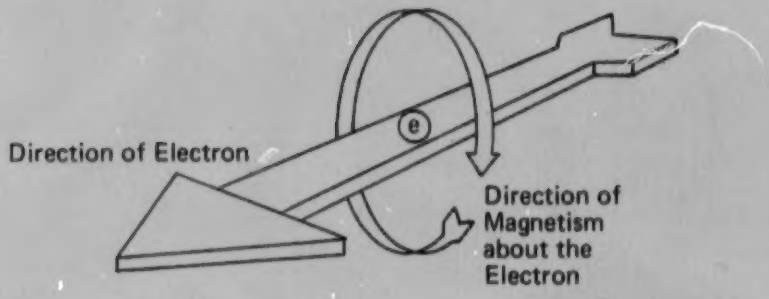
2. Answers should include any seven of the following:
   a. Electric motor
   b. Electric generator or alternator
   c. Relay
   d. Solenoid
   e. Transformer
   f. Computer memory system
   g. Tape recorder
   h. Electrical meters
   i. Speakers

3. a.

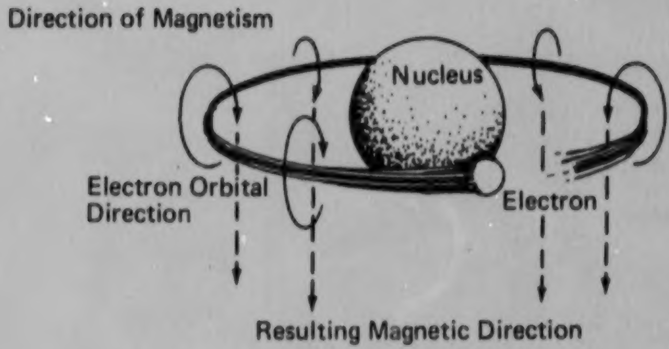

Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Negative
Positive
Battery

ANSWERS TO TEST

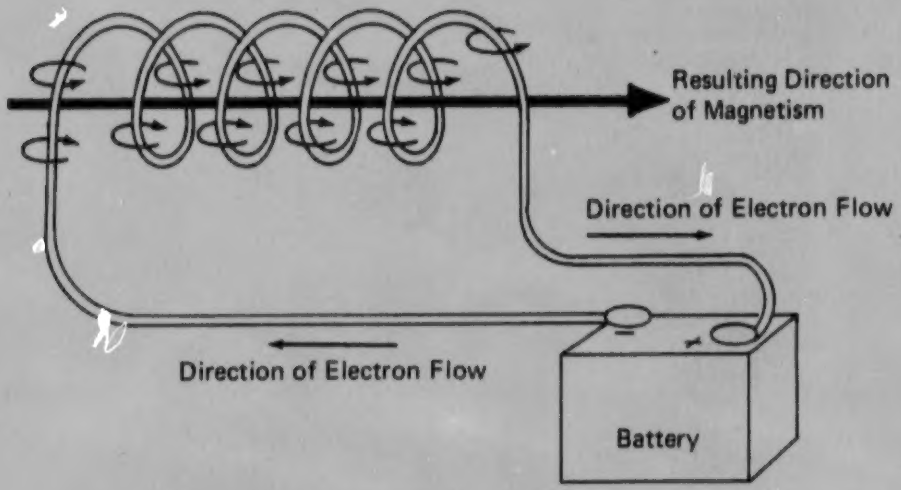
b.


Direction of Electron
e
Direction of Magnetism about the Electron

c.


Direction of Magnetism
Nucleus
Electron Orbital Direction
Electron
Resulting Magnetic Direction

d.


Resulting Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
−
+
Battery

ANSWERS TO TEST

4. If a coil of wire is held in the LEFT hand, the fingers curled around the coils point in the direction of the electron flow, and the extended thumb points in the direction of magnetism, which is called the *north pole*

5. a. NM
   b. M
   c. M
   d. NM
   e. M
   f. NM
   g. NM
   h. M

6. Discussion should include
   a. Magnetic materials--Groups of atoms that act as tiny magnets and can move to alignment in one general direction; the net effect is magnetism
   b. Nonmagnetic materials
      1. Groups of atoms that act as tiny magnets are restricted by their molecular structures from moving into alignment; the net effect is no magnetism
      2. Individual atoms or groups of atoms which have no magnetic polarity at all

7. a. Increase flow of electricity through coils
   b. Increase number of turns of coil
   c. Add type of magnetic core material
   d. Increase diameter of coil

8. a. P
   b. T
   c. P
   d. T
   e. T
   f. P

9. Tendency of magnetic material to not only resist being magnetized and resist having the magnetic direction reversed, but also to retain magnetism

ANSWERS TO TEST

10. a. Initial point
    b. Initial reluctance region
    c. Forward saturation region
    d. Forward residual magnetism point
    e. Forward reluctance region
    f. Forward switching point
    g. Reverse saturation region
    h. Reverse residual magnetism point
    i. Reverse reluctance region
    j. Reverse switching point
11. Evaluated to satisfaction of instructor
12. Evaluated to satisfaction of instructor
13. Evaluated to satisfaction of instructor
14. Performance skills evaluated to satisfaction of instructor

BATTERIES
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to safely take specific gravity readings of a battery, properly connect a battery to a battery charger, and apply correct emergency treatment for acid burns. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with batteries to their correct definitions.
2. Name principal battery applications.
3. Distinguish between circuit characteristics of series and parallel batteries.
4. Define the two basic forms of batteries.
5. Match types of batteries to their correct applications.
6. List basic battery characteristics.
7. Label battery circuit symbols.
8. Define battery capacity.
9. Match specific gravity readings to their indicated state of charge at 80°F.
10. Calculate temperature-corrected specific gravity readings.
11. Arrange in order battery charging procedures.
12. Match lead-acid battery components to their correct chemical composition.
13. Discuss chemical activity that takes place in a lead-acid storage battery during use and while charging.
14. Name safety procedures for handling electrolytes.
15. Arrange in order emergency treatment for acid burns to the skin and eye.
16. Sketch battery circuit schematic diagrams.
17. Determine circuit characteristics of battery circuits.
18. Demonstrate the ability to
    a. Construct a simple saltwater cell.
    b. Give temperature-corrected values from specific gravity readings.
    c. Connect a battery to a charger.

BATTERIES
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Display equipment used in assignment and job sheets.

   H. Display various types of batteries cut in two, showing the material inside.

   I. Give test.

II. Instructional materials

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM #1--Lead-Acid Battery Chemical Composition

      2. TM #2--Chemical Activity During Use

      3. TM #3--Chemical Activity During Charging

   D. Assignment sheets

      1. Assignment Sheet #1--Calculate Temperature-Corrected Specific Gravity Readings

      2. Assignment Sheet #2--Sketch Battery Circuit Schematic Diagrams

      3. Assignment Sheet #3--Determine Circuit Characteristics of Battery Circuits

   E. Answers to assignment sheets

SUGGESTED ACTIVITIES

F. Job sheets

  1. Job Sheet #1--Construct a Simple Saltwater Cell

  2. Job Sheet #2--Give Temperature-Corrected Values from Specific Gravity Readings

  3. Job Sheet #3--Connect a Battery to a Charger

G. Test

H. Answers to test

III. Unit references

A. Jones, E.W. *General Electricity.* Bloomington, Illinois: McKnight and McKnight Publishing Co., 1954.

B. Loper, Orla E. *Direct Current Fundamentals.* Albany, New York: Delmar Publishers, 1963.

C. Mennie, Don. "Batteries: Today and Tomorrow." *IEEE Spectrum.* New York: The Institute of Electrical and Electronics Engineers, Inc., 1978.

D. *Standard First Aid and Personal Safety.* 1st ed., Garden City, New York: Doubleday and Company, Inc. (Prepared by the American National Red Cross), 1973.

BATTERIES
UNIT III

INFORMATION SHEET

I. Terms and definitions

   A. Ampere--Measurement of electrical current flow

   B. Power--Energy; product of voltage times current

   C. Corrode--Process of being chemically etched, or of reacting with elements to produce rust or scale

   D. Voltage reference--Voltage used in equipment as a gauge or constant for comparison

   E. Cell--One set of plates immersed in chemical electrolyte

   F. Battery--More than one connected cell; usually in one container

   G. Specific gravity--Comparison of the weight of a substance to the weight of an equal volume of pure water at the same temperature which is given the value of one

   H. Hydrometer--Instrument for measuring specific gravity of liquids

   I. Electrolyte--Substance in a battery which creates chemical activity

   J. Atom--Smallest particle of an element

   K. Molecule--Combination of attached atoms

   L. Ion--Atom or molecule having either too many or too few electrons

   M. Electron--Negatively-charged part of the atom that constitutes electricity

   N. Oxide--Any chemical or substance with oxygen atoms

   O. Plate--Internal metal part of a battery cell

II. Principal battery applications

   A. Portable power

   B. Emergency power

   C. Instrument reference voltage

   (NOTE: These non-portable test instruments powered by alternating current may also contain batteries for precision reference voltage.)

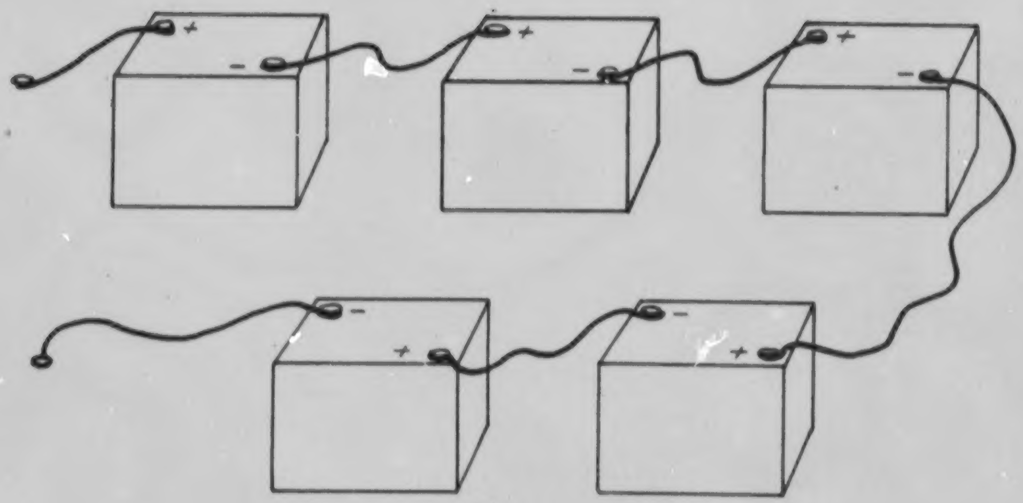
INFORMATION SHEET

III. Circuit characteristics

A. Series battery

1. Circuit configuration (Figure 1)

FIGURE 1



2. Interconnections--Positive terminals connected to negative terminals in succession

3. Voltage output--Equals the sum of each battery's voltage; batteries may be of different voltages

4. Amperage output--Equals that of a single battery; each battery must have the same amperage capacity

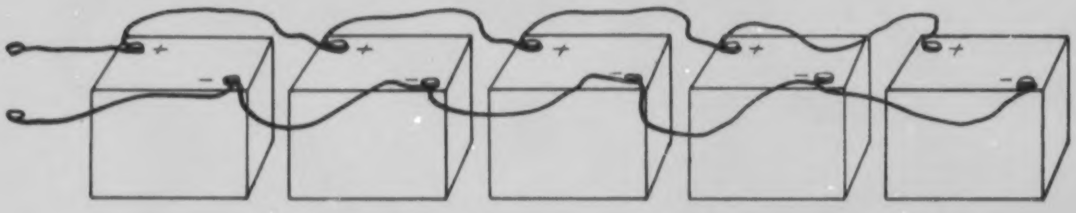
5. Power--Equals the sum of each battery's power

INFORMATION SHEET

B. Parallel battery

1. Circuit configuration (Figure 2)

FIGURE 2



2. Interconnections--All positive terminals connected; all negative terminals connected

3. Voltage output--Equals the voltage of a single battery; batteries must all be of the same voltage

4. Amperage output--Equals the sum of each battery's amperage; batteries may be of different amperage capacities

5. Power--Equals the sum of each battery's power

   (NOTE: The power is the same for either the parallel or series connection.)

IV. Two basic forms of batteries

A. Primary cell--Non-rechargeable dry or wet cell batteries with 1.5 volts per cell

B. Secondary cell--Rechargeable storage batteries with 2 to 2.2 volts per cell

V. Battery types and application

A. Calcium-lead--Rechargeable, gelled battery used for large, portable test equipment and lanterns

B. Carbon-zinc--Non-rechargeable; common flashlight battery

INFORMATION SHEET

C. Lead-acid--Rechargeable, vented, liquid-cell battery for automobiles and emergency power

D. Mercury-oxide--Compact size; used for instrument voltage reference

E. Nickle-cadmium (Ni-Cad)--Rechargeable, sealed battery for small, portable test equipment, certain automobile batteries, and aircraft

F. Zinc-chloride--Improved flashlight battery; less likely to corrode inside the equipment when left unattended for an extended length of time

VI. Basic battery characteristics

A. Dependent on electrochemical action

B. Made of cells

C. Rated according to ampere-hour capacity

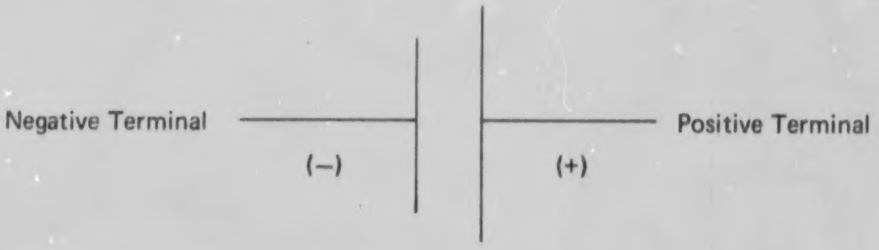
D. Sensitive to temperature, if extremely high or low

E. Dependent on proper maintenance for reliable performance

VII. Battery circuit symbols (Figures 3 and 4)

A. Single cell

FIGURE 3



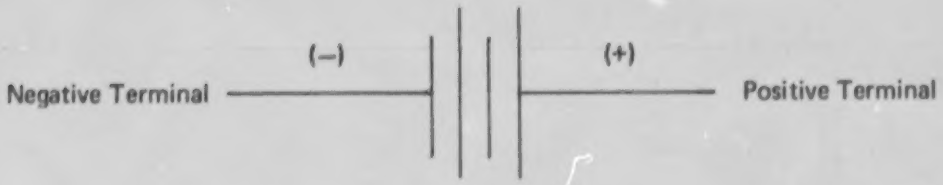
(NOTE: The end with the *shortest parallel line* always represents the negative terminal.)

INFORMATION SHEET

B. Multi-cell battery

(NOTE: The term *battery* originally meant several "cells"; thus, a flashlight does not contain batteries but instead contains *a* battery consisting of two cells. Since an automobile battery has several cells it is properly called a battery.)

FIGURE 4



VIII. Battery capacity--Amount of electric currect a battery will deliver constantly over a specified length of time before the voltage weakens to a certain level

EXAMPLE: A typical automobile battery is rated at 70 ampere-hours (70 Ah). It should deliver an electric current of 70 amperes for a period of one hour before the voltage falls to a certain level. That same battery could have delivered 35 amperes for two hours, 10 amperes for 7 hours.

IX. Specific gravity readings and their indicated states of charge at 80°F (26.7°C)

SPECIFIC GRAVITY READINGS	STATES OF CHARGE INDICATED
1.28	Fully charged
1.25	75% charged
1.22	50% charged
1.19	25% charged
1.16	Hardly useful
1.13	Discharged

(NOTE: There is a .03 difference between each of the specific gravity readings.)

INFORMATION SHEET

X. Specific gravity temperature corrections

A. 80°F (26.7°C) is the standard temperature at which storage batteries are rated

B. For each 10°F (5.6°C) increment above 80°F (26.7°C), add .004 to the hydrometer reading

C. For each 10°F (5.6°C) increment below 80°F (26.7°C), subtract .004 from the hydrometer reading

EXAMPLE 1: Hydrometer reading: 1.235
Temperature: 100°F

Step 1:

100°F - 80°F = 20°F

(NOTE: The temperature is 20°F above the standard.)

Step 2:

20°F ÷ 10°F = 2

(NOTE: There are two 10°F increments.)

Step 3:

2 x .004 = .008

(NOTE: .008 must be added to the original hydrometer reading.)

Step 4:

$$\text{Corrected specific gravity} = \begin{array}{r} 1.235 \\ +.008 \\ \hline 1.243 \end{array}$$

EXAMPLE 2: Hydrometer reading: 1.215
Temperature: 55°F

Step 1:

80°F - 55°F = 25°F

(NOTE: The temperature is 25°F below the standard.)

Step 2:

25°F ÷ 10°F = 2.5

(NOTE: There are 2.5, 10°F increments.)

INFORMATION SHEET

Step 3:

$2.5 \times .004 = .010$

Step 4:

Corrected specific gravity = $\begin{array}{r} 1.215 \\ -.010 \\ \hline 1.205 \end{array}$

XI. Battery charging procedures

(NOTE: These procedures are for ventilated liquid cell, lead-acid batteries only.)

A. Wear protective equipment

1. Safety goggles
2. Rubber or plastic apron
3. Rubber or plastic gloves

B. Provide for well-ventilated work area

C. Remove vent caps to allow explosive hydrogen gas to escape freely

(CAUTION: Prevent sparks or flames near battery while charging.)

D Take hydrometer readings before charging

(CAUTION: Battery may have ice inside if it has been sitting at below freezing temperatures. NEVER charge a frozen battery. Ice seals the gas inside and allows pressure to reach dangerous levels.)

E. Fill cells to proper level using distilled water

(NOTE: Very clean tap water is often acceptable in place of distilled water. Students should ask their instructor, and technicians should ask their foreman or supervisor which type of water to use. New "dry-charged" batteries require the first filling to be of an electrolyte. Read instructions furnished with the battery or check with your supplier.)

F. Connect battery charger clip marked with a plus sign (+), the word *positive*, or colored red to the positive battery post, and connect the clip marked with a minus sign (-), the word *negative*, or colored black to the negative battery post

(NOTE: Black and red are standard color codes to designate negative and positive.)

INFORMATION SHEET

G. Select desired charging rate and time to charge

(NOTE: If it is completely discharged, a 70 ampere-hour battery could be charged at 7 amps for 10 hours, 10 amps for 7 hours, 5 amps for 14 hours, and so on.)

H. To verify that all cells are charged, retake hydrometer readings after charging

I. Refill with water if necessary

(NOTE: If considerable amounts of water are added, battery may require additional charging.)

XII. Lead-acid battery components (Transparency #1)

A. Negative plate--Composed of lead molecules, designated by the letters *Pb*

B. Positive plate--Composed of lead dioxide molecules (one lead atom and two oxygen atoms, PbO_2), designated by the letter *O*

C. Electrolyte components

1. Water--Composed of dihydrogen oxide molecules (one oxygen atom and two hydrogen atoms, H_2O), designated by the letter *H*
2. Sulfuric acid--Composed of dihydrogen sulfuric tetroxide molecules (two hydrogen atoms, one sulfur atom, and four oxygen atoms, H_2SO_4), designated by the letter *S*

D. Electrolyte solution--Composed of the water molecules and the sulfuric acid molecules; the sulfuric acid molecules separate in the solution into positive hydrogen ions and negative sulfur oxide ions

(NOTE: Ions are designated by a (+) or (-) to show that they lack electrons or have an excess of electrons.)

XIII. Chemical activity of lead-acid storage batteries during use and charging

A. During use (Transparency #2)

1. Electrolyte is broken down into its elements
2. Hydrogen, in the form of ions, goes to the lead plate, causing the terminal to become negatively charged; *pure lead*
3. Oxygen, in the form of ions, goes into the electrolyte, causing the terminal to become positively charged; *lead-dioxide*
4. Cell now contains two different electrodes in the electrolyte, producing a current
5. When the cell is discharged, sulfuric acid in the electrolyte acts on both plates, changing them both to lead-sulfate

INFORMATION SHEET

6. When lead-sulfate is formed, water is also produced, causing the electrolyte to be diluted or weakened, and the cell must be recharged

B. During charging (Transparency #3)

   1. Water molecules separate into hydrogen and oxygen ions

      a. Oxygen ions--Attracted to the positive plate where they recombine with the lead atoms to reform the lead-dioxide

      b. Hydrogen ions--Attracted to the negative plate where they form gas bubbles and ventilate from the battery

      (NOTE: This is why water must be added to the battery; to replace that lost by these chemical actions. This is also the source of the explosive hydrogen gas that occurs during charging.)

   2. Sulfur-oxide ions re-enter the solution from both plates

      a. Negative plate--Returns to original state of uncombined lead molecules

      b. Positive plate--Returns to original state of lead-dioxide

      c. Solution--Becomes more concentrated and heavier as more sulfur-oxide ions enter; this can be measured with the hydrometer

XIV. Safety measures for handling electrolytes

A. Wear protective garments

   1. Safety goggles

   2. Rubber or plastic apron

   3. Rubber or plastic gloves

B. Never pour water into a strong acid; chemical reaction can cause it to splatter onto skin or into the eyes

(NOTE: If a strong acid must be diluted, pour acid slowly into a glass or plastic vessel of water.)

XV. Emergency treatment for serious acid burns

A. Acid burns of the skin

   1. Flush area with large amount of water for at least five minutes

   2. Remove clothing from areas involved

INFORMATION SHEET

3. Apply sterile dressing to severe burns

4. Get immediate medical attention for serious burns

   (CAUTION: Do not apply any substance to a major burn other than plenty of water and a sterile bandage. Apply burn ointment to MINOR burns only.)

B. Acid burns of the eye

1. Immediately and thoroughly flush the face, eyelids, and eyes with large amount of water for at least five minutes, holding eye open, if necessary

   (CAUTION: If victim is lying down, turn head to one side so that the affected eye is on the bottom, and pour water from the inner corner of the eye outward; eye must be open.)

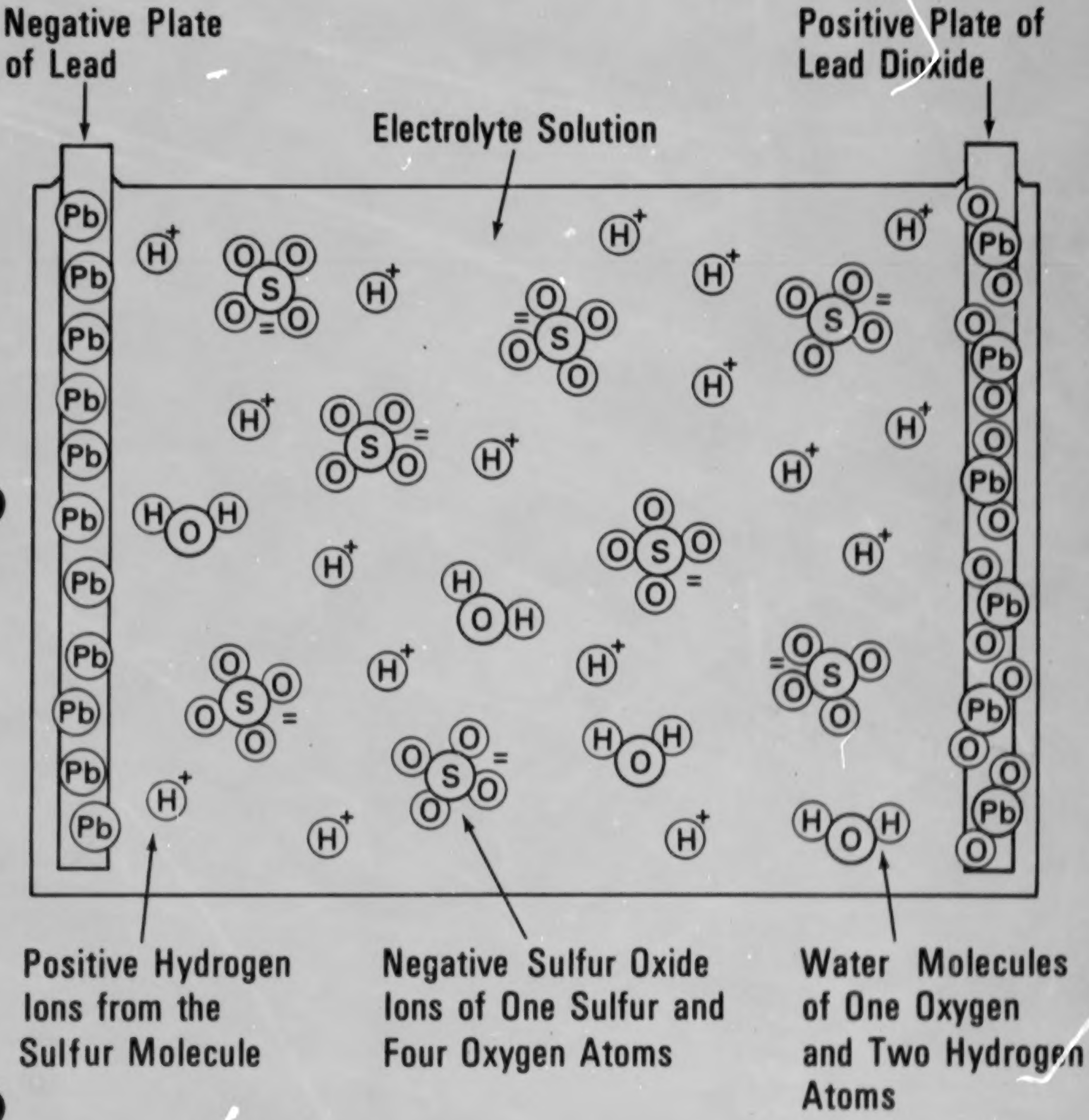
   (NOTE: If baking soda is immediately available, flush eye with a weak solution made from one teaspoonful baking soda added to one quart of water.)

2. Cover eye with clean, dry, protective bandage

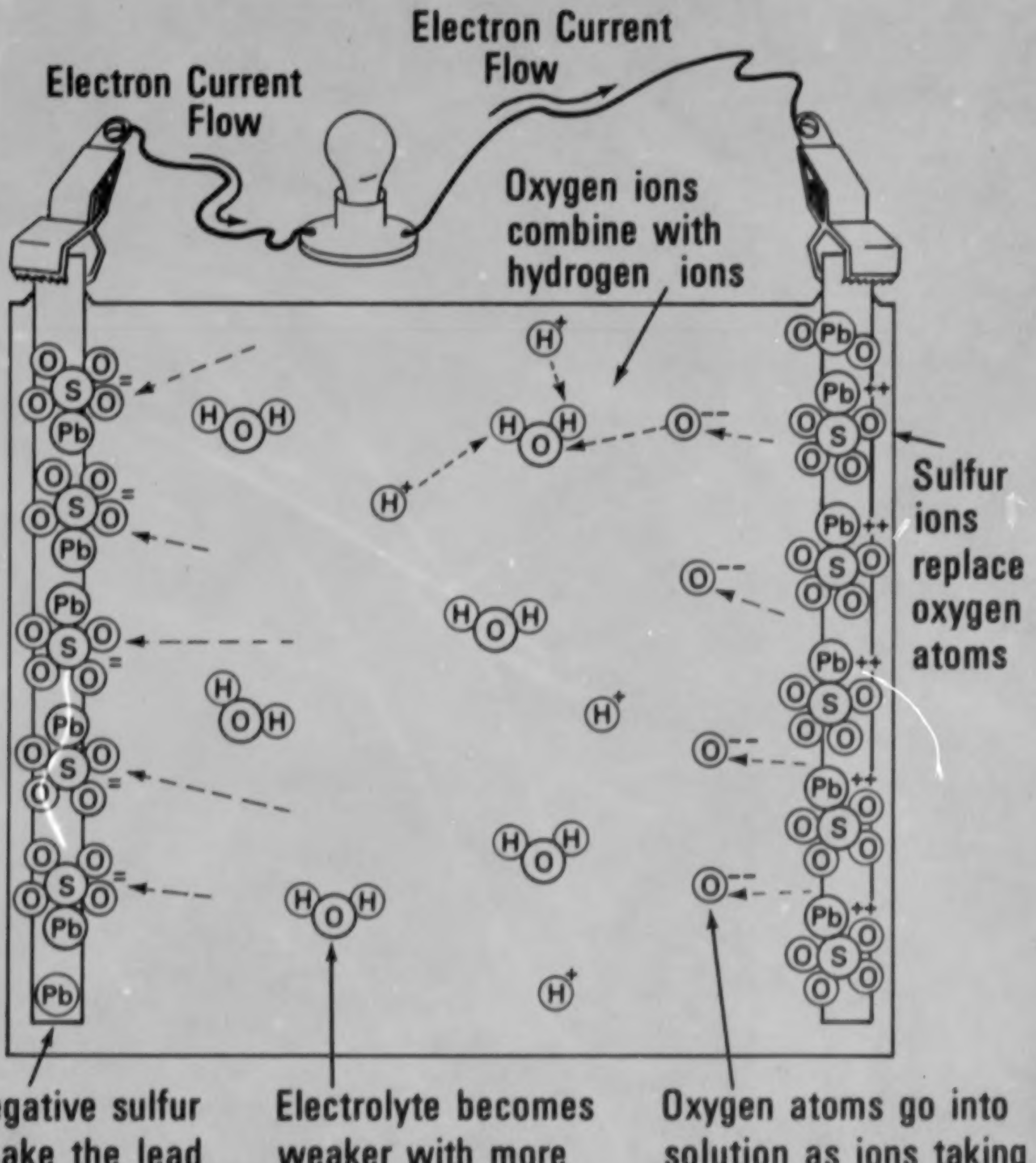
   (CAUTION: Do not use cotton as it may stick to burned area. Do not let victim rub eye.)

3. Get immediate medical attention from an eye specialist, if possible

Lead-Acid Battery Chemical Composition


Negative Plate of Lead
Positive Plate of Lead Dioxide
Electrolyte Solution
Pb
O
S
H+
H
=
Positive Hydrogen Ions from the Sulfur Molecule
Negative Sulfur Oxide Ions of One Sulfur and Four Oxygen Atoms
Water Molecules of One Oxygen and Two Hydrogen Atoms

Chemical Activity During Use

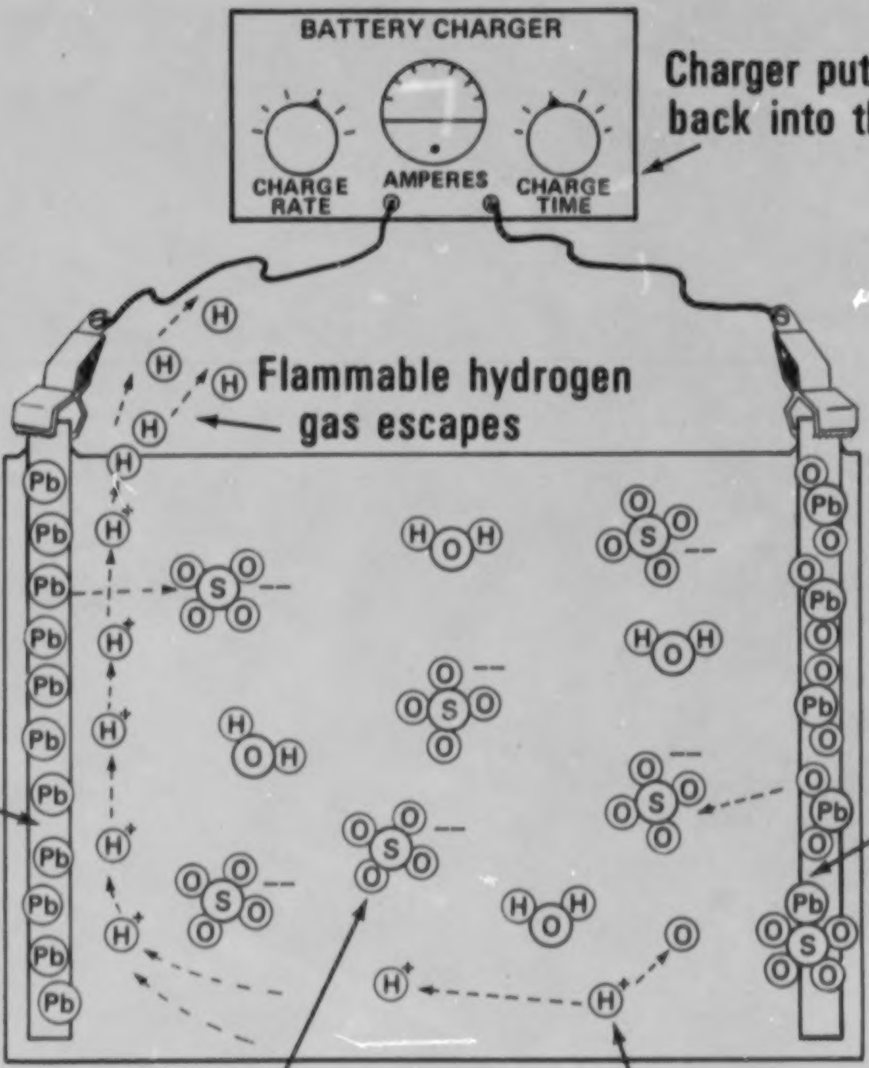

Electron Current Flow
Electron Current Flow
Oxygen ions combine with hydrogen ions
Sulfur ions replace oxygen atoms
Pb
S
O
H
O^{--}
H^+
Pb^{++}

The negative sulfur ions make the lead plate negative

Electrolyte becomes weaker with more water molecules and lighter with fewer sulfur-oxide ions

Oxygen atoms go into solution as ions taking more electrons from the plate than the sulfur ions bring to it

Chemical Activity During Charging



Charger puts energy back into the battery

Flammable hydrogen gas escapes

Negative plate is changed back to lead as the sulfur-oxide ions depart

Positive plate is changed back to lead-dioxide as the sulfur-oxide ions depart and oxygen atoms arrive

Electrolyte becomes stronger and heavier as more sulfur-oxide ions enter solution

Water molecules are separated; oxygen atoms go to the positive plate; hydrogen atoms go to the negative plate; water is used and must be replaced;

BATTERIES
UNIT III

ASSIGNMENT SHEET #1--CALCULATE TEMPERATURE-CORRECTED SPECIFIC GRAVITY READINGS

NAME ______________________________ SCORE ______________

Because the battery charge indicated by a specific gravity reading is only accurate at 80°F (26.7°C), readings at other temperatures must be corrected before the charge can be determined. For each specific gravity reading and temperature given below, calculate the temperature-corrected specific gravity and the indicated state of charge. Place your answers in the spaces provided. Consult your instructor when you have finished.

SPECIFIC GRAVITY READINGS	ELECTROLYTE TEMPERATURES		TEMPERATURE-CORRECTED SPECIFIC GRAVITY	INDICATED STATE OF CHARGE
1.210	85°F (29.4°C)	a.	________	________
1.280	55°F (12.8°C)	b.	________	________
1.200	125°F (51.7°C)	c.	________	________
1.190	70°F (21.1°C)	d.	________	________
1.255	75°F (23.9°C)	e.	________	________

BATTERIES
UNIT III

ASSIGNMENT SHEET #2–SKETCH BATTERY CIRCUIT SCHEMATIC DIAGRAMS

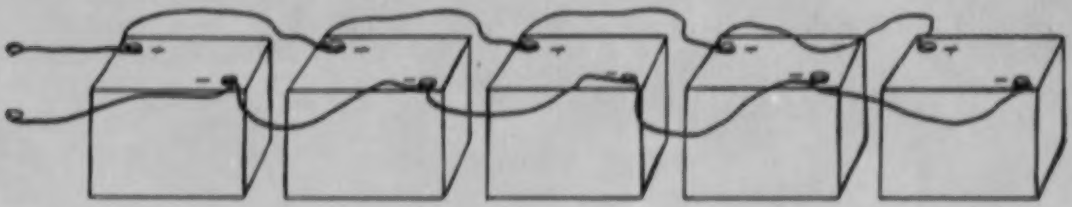
NAME ______________________________ SCORE ______________

Use the battery symbol and sketch the circuits below (Figures 5 and 6) as schematic diagrams.

(NOTE: Merely replace the pictures of batteries with the symbol, and sketch all wires as straight lines.)

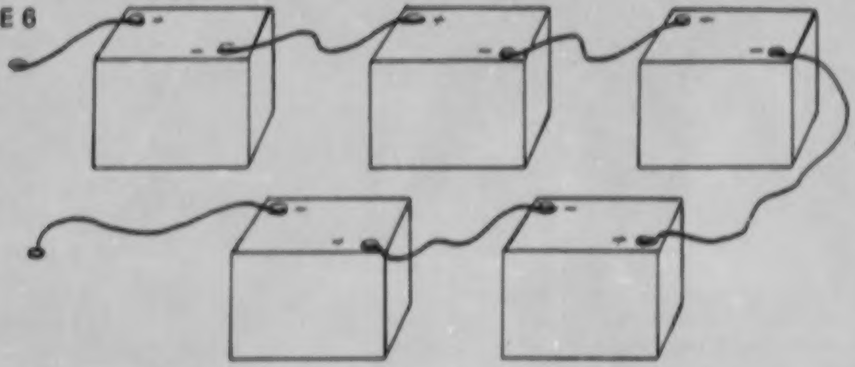
1. Series circuit schematic

FIGURE 5



2. Parallel circuit schematic

FIGURE 6



BATTERIES
UNIT III

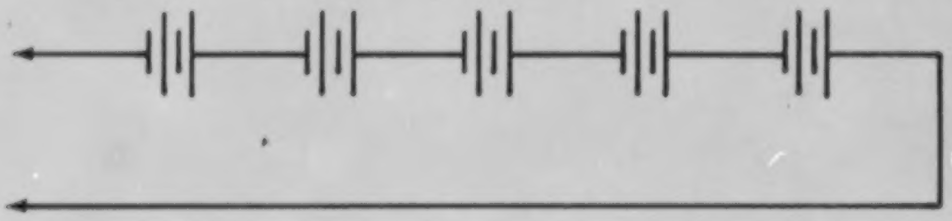
ASSIGNMENT SHEET #3–DETERMINE CIRCUIT CHARACTERISTICS OF BATTERY CIRCUITS

NAME ______________________________ SCORE ______________

Industry often uses many storage batteries interconnected for emergency power for lighting, computers and vital control circuits, and large engine starting. These batteries may fill an entire room, and can be interconnected in various ways. If the batteries diagrammed in Figures 7-9 are each 24 volts and 100 amperes, determine the output voltage and electric current capacity of each circuit. Write your answers in the spaces provided.

1.

FIGURE 7

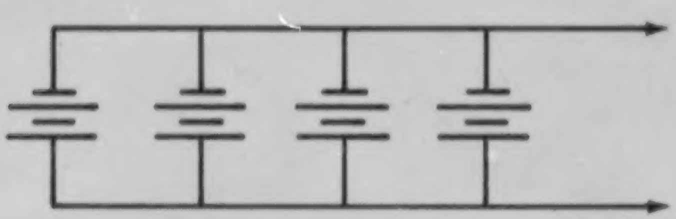


a. Voltage output = ______________________________ volts

b. Current output = ______________________________ amperes

2.

FIGURE 8



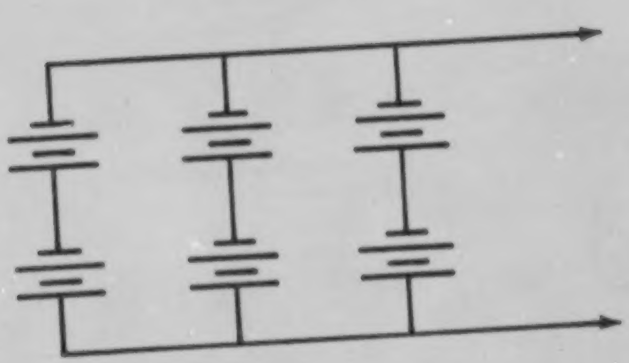
a. Voltage output = ______________________________ volts

b. Current output = ______________________________ amperes

ASSIGNMENT SHEET #3

3.

FIGURE 9



a. Voltage output = ______________________ volts

b. Current output = ______________________ amperes

BATTERIES
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

a. 1.212--50% charged

b. 1.270--Almost fully charged

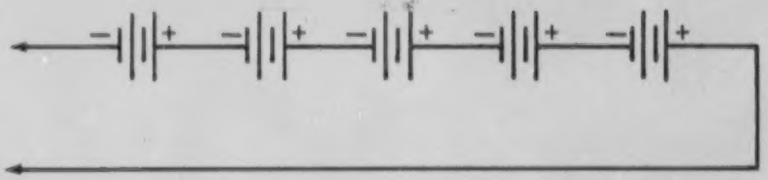
c. 1.218--50% charged

d. 1.186--25% charged

e. 1.253--75% charged

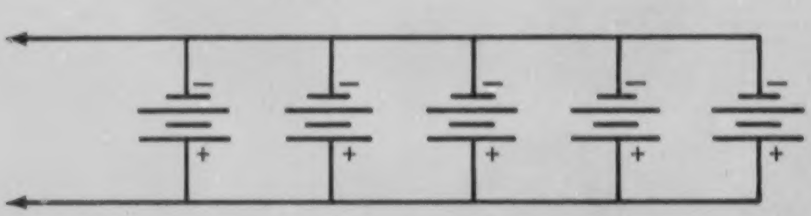
Assignment Sheet #2

1. Series schematic circuit



(NOTE: Negative terminals must be shown connected to positive terminals as above.)

2. Parallel schematic circuit



(NOTE: All negative terminals must be shown connected to each other, and all positive terminals must be shown connected to each other as above.)

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #3

1. a. 120 volts
   b. 100 amperes
2. a. 24 volts
   b. 400 amperes
3. a. 48 volts
   b. 300 amperes

BATTERIES
UNIT III

JOB SHEET #1--CONSTRUCT A SIMPLE SALTWATER CELL

I. Equipment and materials

A. Multimeter--Range capacity between 0.1 volt to 1.0 volt

B. Glass or plastic beaker or wide-mouth jar--1 pint to 1 quart capacity

C. Bare solid copper wire--AWG #14, about 8 inches in length

D. Bare steel wire--Size similar to copper wire

E. Table salt--About 2 tablespoons

II. Procedure

A. Place one end of the two wires into the beaker of fresh water so that they are not touching; leave the other ends above the water

B. Measure the voltage of the two wires by connecting the two leads of the multimeter to the two wires

(NOTE: If you do not know how to operate the multimeter, ask your instructor for assistance.)

C. Record results below

Voltage measurement of water ______________________

D. Add the salt slowly while stirring the solution and observing the voltage indication on the multimeter

E. Record your saltwater voltage measurement below

Voltage measurement of saltwater ______________________

(NOTE: Show your voltage reading to the instuctor. If a weak solution of sulfuric acid is available, instructor may permit you to repeat the job sheet using electrolyte in place of salt.)

(CAUTION: If electrolyte is used, pour only a small amount into the beaker after having filled it about one-half full with fresh water.)

F. Put equipment and materials away

BATTERIES
UNIT III

JOB SHEET #2--GIVE TEMPERATURE-CORRECTED VALUES FROM SPECIFIC GRAVITY READINGS

I. Equipment and materials

A. Hydrometer

B. Thermometer--Glass rod type

C. Protective equipment--Safety goggles, rubber or plastic apron, rubber or plastic gloves

D. Lead-acid storage battery

II. Procedure

A. Put on protective equipment

B. Provide for well-ventilated working area

C. Remove battery vent caps

D. Squeeze hydrometer bulb slightly and hold

E. Place hydrometer tube in cell and release pressure on bulb to draw electrolyte into chamber

(NOTE: There must be enough electrolyte drawn up into the chamber to float the indicator inside.)

F. Without removing the hydrometer, record the reading below

Cell #1__________ Cell #2__________ Cell #3__________

Cell #4__________ Cell #5__________ Cell #6__________

G. Squeeze bulb to return electrolyte to the cell

H. Repeat steps D through G above until all of the battery's cells have been measured and recorded

(CAUTION: While carrying the hydrometer or changing it from one cell to another, do not allow droplets to be flipped from the end of the rubber tube. These droplets will burn clothing, skin, and eyes. Do not remove your protective equipment until AFTER step J.)

JOB SHEET #2

I. Measure the temperature and record below

Cell #1__________ Cell #2__________ Cell #3__________

Cell #4__________ Cell #5__________ Cell #6__________

(NOTE: Unless the battery has been undergoing a rapid charge or discharge, the temperature of the room will be the same as that of the battery, and the battery temperature will not have to be measured directly.)

J. Flush hydrometer, and rinse thermometer

K. Remove protective equipment, and wash your hands

L. Make temperature corrected specific gravity readings (unless hydrometer is the type which gives corrected reading) and determine the state of charge of each cell; record below

Cell #1__________ Cell #2__________ Cell #3__________

Cell #4__________ Cell #5__________ Cell #6__________

(NOTE: Show your results to the instructor.)

M. Put equipment and materials away

BATTERIES
UNIT III

JOB SHEET #3--CONNECT A BATTERY TO A CHARGER

I. Equipment and materials

- A. Lead-acid battery
- B. Battery charger--Voltage capability of battery above
- C. Protective equipment--Safety goggles, rubber or plastic apron, rubber or plastic gloves
- D. Distilled water

II. Procedure

- A. Put on protective equipment
- B. Provide for well-ventilated working area
- C. Remove battery vent caps
- D. Take hydrometer readings and record them for later reference

  Cell #1__________ Cell #2__________ Cell #3__________
  Cell #4__________ Cell #5__________ Cell #6__________

- E. Fill each cell with distilled water
- F. Connect the charger cables to the battery, making certain that the positive cable goes to the positive post and the negative cable goes to the negative post
- G. Select the desired charging rate
- H. Turn the charger on
- I. Check the charge rate indicator or amperes meter for a steady indication that corresponds to the rate selected
- J. After charging, take hydrometer readings again to verify that all cells are properly charged

  Cell #1__________ Cell #2__________ Cell #3__________
  Cell #4__________ Cell #5__________ Cell #6__________

- K. Add more water if necessary
- L. Replace vent caps
- M. Put equipment and materials away

BATTERIES
UNIT III

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with batteries to their correct definitions. Write the correct numbers in the blanks.

_____a. Smallest particle of an element

_____b. Internal metal part of a battery cell

_____c. One set of plates immersed in chemical electrolyte

_____d. Energy; product of voltage times current

_____e. Comparison of weight of a substance to the weight of an equal volume of pure water at the same temperature which is given the value of one

_____f. Measure of electrical current flow

_____g. Any chemical or substance with oxygen atoms

_____h. Substance in a battery which creates chemical activity

_____i. Combination of attached atoms

_____j. Process of being chemically etched, or of reacting with elements to produce rust or scale

_____k. More than one connected cell; usually in one container

_____l. Negatively-charged part of atom that constitutes electricity

_____m. Instrument for measuring specific gravity of liquids

_____n. Voltage used in equipment as a gauge or constant for comparison

_____o. Atom or molecule having either too many or too few electrons

1. Ampere
2. Power
3. Corrode
4. Voltage reference
5. Cell
6. Battery
7. Specific gravity
8. Hydrometer
9. Electrolyte
10. Atom
11. Molecule
12. Ion
13. Electron
14. Oxide
15. Plate

TEST

2. Name principal battery applications.

a. ______________________________

b. ______________________________

c. ______________________________

3. Distinguish between circuit characteristics of series and parallel batteries. Write an "S" for characteristics of a series battery and a "P" for characteristics of a parallel battery. Some blanks may have both series and parallel characteristics.

______a. Power equals the sum of each battery's power

______b. Amperage output equals the sum of each battery's amperage; batteries may be of different amperage capacities

______c. Amperage output equals that of a single battery; each battery must have same amperage capacity

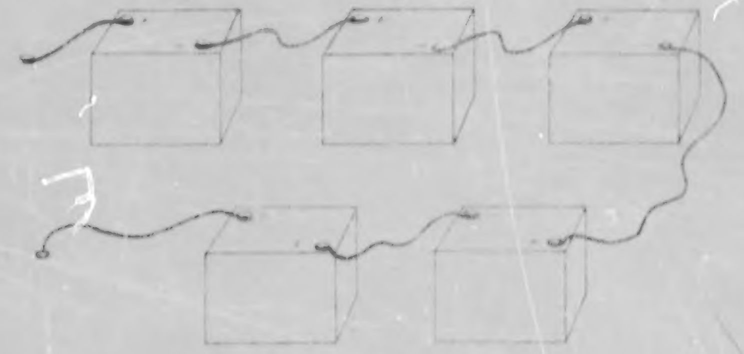
______d. Voltage output equals sum of each battery's voltage; batteries may be of different voltages

______e. Voltage output equals voltage of a single battery; batteries must all be of the same voltage

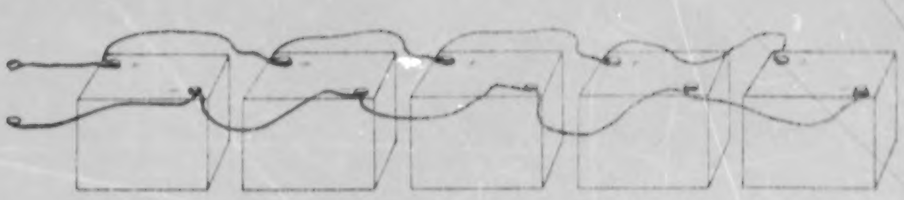
______f. All positive terminals connected; all negative terminals connected

______g. Positive terminals connected to negative terminals in succession

______h.



______i.



TEST

4. Define the two basic forms of batteries.

   a. Primary cell-- ____

   ____

   b. Secondary cell-- ____

   ____

5. Match types of batteries to their correct applications. Write the correct numbers in the blanks.

_____a. Rechargeable, gelled battery used for large, portable test equipment and lanterns

_____b. Non-rechargeable; common flashlight battery

_____c. Improved flashlight battery; less likely to corrode inside the equipment when left unattended for an extended length of time

_____d. Rechargeable, sealed battery for small, portable test equipment, certain automobile batteries, and aircraft

_____e. Rechargeable, vented, liquid-cell battery for automobiles and emergency power

_____f. Compact size; used for instrument voltage reference

1. Calcuim-lead
2. Carbon-zinc
3. Lead-acid
4. Mercury-oxide
5. Nickle-cadmium (Ni-cad)
6. Zinc-chloride

6. List the basic characteristics of batteries.

   a. ____

   b. ____

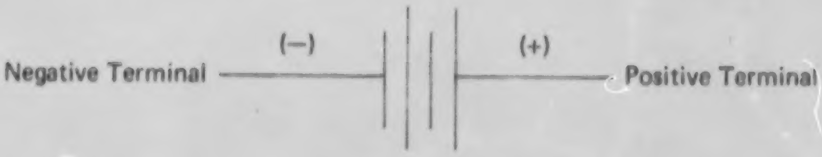
   c. ____

   d. ____

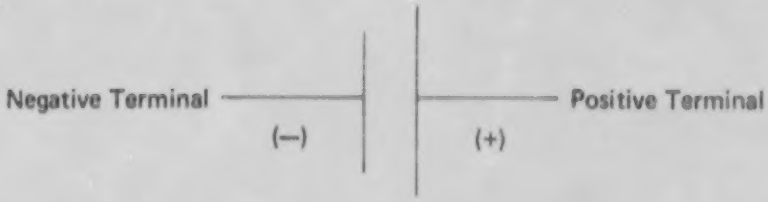
   e. ____

TEST

7. Label battery circuit symbols. Write the correct names in the blanks.


Negative Terminal
(−)
(+)
Positive Terminal

a. ______________________________


Negative Terminal
(−)
(+)
Positive Terminal

b. ______________________________

8. Define battery capacity.

____

____

____

9. Match specific gravity readings to their indicated state of charge at 80°F. Write the correct numbers in the blanks.

_____a. 25% charged	1. 1.28
_____b. Discharged	2. 1.25
_____c. 75% charged	3. 1.22
_____d. Hardly useful	4. 1.19
_____e. 50% charged	5. 1.16
_____f. Fully charged	6. 1.13

TEST

10. Calculate specific temperature-corrected gravity readings listed below.

a. Hydrometer reading: 1.215

Temperature: 55°F

Corrected specific gravity = ____________________

b. Hydrometer reading: 1.235

Temperature: 100°F

Corrected soecific gravity = ____________________

11. Arrange in order battery charging procedures. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. Connect battery charger clip marked with a plus sign (+), the word *positive*, or colored red to the positive battery post, and connect clip marked with a minus sign (-), the word *negative*, or colored black to the negative battery post

_____b. Refill with watery if necessary

_____c. Fill cells to proper level using distilled water

_____d. Wear protective equipment

_____e. Take hydrometer readings before charging

_____f. Select desired charging rate and time to charge

_____g. Remove vent caps to allow explosive hydrogen gas to freely escape

_____h. To verify that all cells are charged, retake hydrometer readings

_____i. Provide for well-ventilated work area

TEST

12. Match lead-acid battery components to their correct chemical compositions. Write the correct numbers in the blanks.

_____a. Composed of dihydrogen sulfuric tetroxide molecules (two hydrogen atoms, one sulfur atom, and four oxygen atoms, H_2SO_4), designated by the letter *S*

_____b. Composed of lead dioxide molecules (one lead atom and two oxygen atoms, PbO_2), designated by the letter *O*

_____c. Composed of lead molecules, designated by the letters *Pb*

_____d. Composed of water molecules and sulfuric acid molecules; sulfuric-acid molecules separate in the solution into positive hydrogen ions and negative sulfur oxide ions

_____e. Composed of dihydrogen oxide molecules (one oxygen atom and two hydrogen atoms, H_2O), designated by the letter *H*

1. Negative plate
2. Positive plate
3. Water
4. Sulfuric acid
5. Electrolyte solution

13. Discuss in a short paragraph the chemical activity that takes place in a lead-acid storage battery during use and while charging.

TEST

14. Name safety procedures for handling electrolytes.

    a. ____

    ____

    b. ____

    ____

15. Arrange in order the steps for emergency treatment for acid burns to the skin and eyes. Write a "1" before the first step, a "2" before the second step, and so on.

    a. Acid burns to the skin

    ______1. Get immediate medical attention for serious burns

    ______2. Remove clothing from areas involved

    ______3. Apply sterile dressing to severe burns

    ______4. Flush area with large amount of water for at least five minutes

    b. Acid burns of the eyes

    ______1. Get immediate medical attention from an eye specialist, if possible

    ______2. Immediately and thoroughly flush the face, eyelids, and eyes with large amount of water for at least five minutes, holding eye open, if necessary

    ______3. Cover eye with clean, dry, protective bandage

(NOTE: Test questions 16, 17, and 18 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

16. Sketch battery circuit schematic diagrams.

17. Determine circuit characteristics of battery circuits.

18. Demonstrate the ability to

    a. Construct a simple saltwater cell.

    b. Give temperature-corrected values from specific gravity readings.

    c. Connect a battery to a charger.

BATTERIES
UNIT III

ANSWERS TO TEST

1. a. 10
   b. 15
   c. 5
   d. 2
   e. 7
   f. 1
   g. 14
   h. 9
   i. 11
   j. 3
   k. 6
   l. 13
   m. 8
   n. 4
   o. 12
2. a. Portable power
   b. Emergency power
   c. Instrument reference voltage
3. a. S, P
   b. P
   c. S
   d. S
   e. P
   f. P
   g. S
   h. S
   i. P
4. a. Non-rechargeable
   b. Rechargeable storage batteries with 2 to 2.2 volts per cell
5. a. 1
   b. 2
   c. 6
   d. 5
   e. 3
   f. 4
6. a. Dependent on electrochemical action
   b. Made of cells
   c. Rated according to ampere-hour capacity
   d. Sensitive to temperature, if extremely high or low
   e. Dependent on proper maintenance for reliable performance

ANSWERS TO TEST

7. a. Multi-cell battery
   b. Single cell

8. Amount of electric current a battery will deliver constantly over a specified length of time before the voltage weakens to a certain level

9. a. 4
   b. 6
   c. 2
   d. 5
   e. 3
   f. 1

10. a. 1.205
    b. 1.243

11. a. 6
    b. 9
    c. 5
    d. 1
    e. 4
    f. 7
    g. 3
    h. 8
    i. 2

12. a. 4
    b. 2
    c. 1
    d. 5
    e. 3

13. Discussion should include:
    a. During use
       1) Electrolyte is broken down into its elements
       2) Hydrogen, in the form of ions, goes to the lead plate, causing the terminal to become negatively charged; *pure lead*
       3) Oxygen, in the form of ions, goes into the electrolyte, causing the terminal to become positively charged; *lead-dioxide*
       4) The cell now contains two different electrodes in the electrolyte, producing a current
       5) When the cell is discharged, sulfuric acid in the electrolyte acts on both plates, changing them both to lead-sulfate

ANSWERS TO TEST

6) When lead-sulfate is formed, water is also produced, causing the electrolyte to be diluted, or weakened, and the cell must be recharged

b. During charging

    1) Water molecules separate into hydrogen and oxygen ions

        a) Oxygen ions--Attracted to the positive plate where they recombine with the lead atoms to reform the lead-dioxide

        b) Hydrogen ions--Attracted to the negative plate where they form gas bubbles and ventilate from the battery

    2) Sulfur-oxide ions re-enter the solution from both plates

        a) Negative plate--Returns to original state of uncombined lead molecules

        b) Positive plate--Returns to original state of lead-dioxide

        c) Solution--Becomes more concentrated and heavier as more sulfur-oxide ions enter; this can be measured with the hydrometer

14. a. Wear protective garments

    1) Safety goggles

    2) Rubber or plastic apron

    3) Rubber or plastic gloves

    b. Never pour water into a strong acid; chemical reaction can cause it to splatter onto skin or into the eyes

15.

a.	1	4
	2	2
	3	3
	4	1
b.	1	3
	2	1
	3	2

16. Evaluated to satisfaction of instructor

17. Evaluated to satisfaction of instructor

18. Performance skills evaluated to satisfaction of instructor

DC FUNDAMENTALS
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to construct series and parallel resistive circuits having a predetermined resistance, current, and voltage. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with direct current fundamentals to their correct definitions.
2. Name direct current abbreviations and symbols.
3. State Ohm's Law.
4. Calculate electrical properties by using Ohm's Law.
5. Calculate conductance.
6. State how variables affect conductor resistance.
7. Calculate electrical conductor resistance.
8. Calculate the voltage across series resistors.
9. Describe the basic circuit characteristics in series and parallel circuits.
10. State Kirchoff's current and voltage laws.
11. Calculate total current in the simple parallel circuit using Ohm's Law.
12. Apply Ohm's Law to series circuits with multiple components.
13. Calculate the resistor required for a control relay circuit.
14. Determine the correct indications for a conductivity meter.
15. Demonstrate the ability to
    a. Construct a series direct current circuit having a predetermined electrical current flow.
    b. Construct a parallel direct current circuit having a predetermined electrical current flow.
    c. Use a resistor to reduce voltage.

DC FUNDAMENTALS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Provide students with objective sheet.

  B. Provide students with information, assignment, and job sheets.

  C. Make transparencies.

  D. Discuss unit and specific objectives.

  E. Discuss information sheet.

  F. Demonstrate and discuss procedures outlined in assignment and job sheets.

  G. Construct a parallel circuit with an ammeter and variable resistor in each branch.

  H. Demonstrate the current dividing effect of the parallel circuit.

  I. Give test.

II. Instructional materials

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM #1--Basic Electrical Circuit

    2. TM #2--Ohm's Law Memory Wheel

    3. TM #3--American Wire Gauge (AWG)

    4. TM #4--Conductor Resistivities

    5. TM #5--Series Circuit

    6. TM #6--Parallel Circuit

  D. Assignment sheets

    1. Assignment Sheet #1--Apply Ohm's Law to Series Circuits with Multiple Components

SUGGESTED ACTIVITIES

        2. Assignment Sheet #2--Calculate the Resistor Required for a Control Relay Circuit
        3. Assignment Sheet #3--Determine the Correct Indications for a Conductivity Meter

    E. Answers to assignment sheets

    F. Job sheets

        1. Job Sheet #1--Construct a Series Direct Current Circuit Having a Predetermined Current Flow
        2. Job Sheet #2--Construct a Parallel Direct Current Circuit Having a Predetermined Electrical Current Flow
        3. Job Sheet #3--Use a Resistor to Reduce Voltage

    G. Test

    H. Answers to test

III. Unit references

A. Beam, Robert E., ed. *A Dictionary of Electronic Terms.* 7th ed., Chicago, Illinois: Allied Radio, 1963.

B. *Electrical Fundamentals (Direct Current).* Technical Manual No. TM 11-661. Departments of the Army and the Air Force. Washington, D.C.: U.S. Government Printing Office, 1951.

C. Loper, Orla E. *Direct Current Fundamentals.* Albany, New York: Delmar Publishers, 1963.

D. Seippel, Robert G. *Direct Current Circuit Analysis.* Chicago: American Technical Society, 1975.

DC FUNDAMENTALS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Amperage--Measurement unit for a quantity of electrons; electricity; electrical current; current flow

(NOTE: Amperage may also be called *amps* or *amperes*.)

B. Voltage--Measurement unit for electrical potential or electrical force; electromotive force (emf)

(NOTE: Voltage is sometimes referred to as *electrical pressure* or *volts*.)

C. Ohm--Measurement unit for the resistance to electrical current offered by a circuit or device

D. Resistor--Device used to impede electrical current flow or to divide voltages within circuits

E. Resistivity--Specific resistance of materials expressed as ohms per circular mil foot

F. Conductance--Mathematical inverse of resistance

G. Conductivity--Specific conductance of materials; mathematical inverse of resistivity

H. Mho--Measurement unit for conductance of a device or circuit

I. Direct current--Electrical current that moves consistently in only one direction

J. Series circuit--Circuit in which electric current has only one path throughout

K. Mil--One-thousandth of an inch or .001 inches

L. Circular mil--Area contained in a circle having a diameter or one mil

M. Current--Movement of electrons through conductor

II. Direct current abbreviations and symbols

A. A = Amperage, amp

B. V = Voltage, volt

C. R = Resistor

INFORMATION SHEET

D. Ω = Ohm

E. G = Conductance

F. emf = Electromotive force

G. I = Current

H. DC = Direct current

I. -Ⓐ- = Ammeter

J. -Ⓥ- = Voltmeter

K. (Ω) = Ohmmeter

L. ⊣|||⊢ = Battery

M. WW = Resistor

N. Ea = Voltage applied

O. -(⌒)- = Light

P. I_t = Current total

Q. R_t = Resistance total

R. -(↗)- = Meter

III. Ohm's Law

A. Statement of circuit behavior--Amperage through a circuit equals the voltage across the circuit divided by the resistance in the circuit

EXAMPLE: Amperage in a circuit powered by a 12-volt battery and having a resistance of 6 ohms will be equal to 12 divided by 6 or 2 amperes (Transparency #1).

B. Mathematical formula for current--$I = \frac{E}{R}$

C. Mathematical formula for voltage--$E = IR$

D. Mathematical formula for resistance--$R = \frac{E}{I}$

(NOTE: Ohm's Law Memory Wheel shown on Transparency #2 illustrates an easy method for remembering all three mathematical formulas listed above. Each element of the formula can be written by observing the position of the remaining two.)

INFORMATION SHEET

IV. Calculating electrical properties by using Ohm's Law

A. Current--Use the formula $I = \frac{E}{R}$

EXAMPLE: An electrician connects a 50 ohm direct current coil to a 20-volt direct current power supply. What is the electrical current in the circuit?

Solution:
$$I = \frac{E}{R}$$
$$= \frac{20}{50}$$
$$= .4 \text{ amperes}$$

B. Voltage--Use the formula $E = IR$

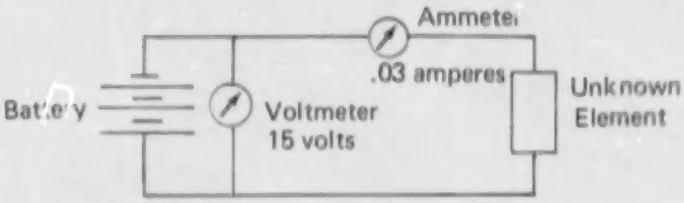
EXAMPLE: A resistor has .05 amperes of electrical current passing through it. The resistor has 5,000 ohms of resistance. What voltage potential is across the resistor?

Solution:
$$E = IR$$
$$= .05 \times 5{,}000$$
$$= 250 \text{ volts}$$

C. Resistance--Use the formula $R = \frac{E}{I}$

EXAMPLE: The circuit diagram in Figure 1 has an unknown element. What is the resistance of the element?

FIGURE 1



Solution:
$$R = \frac{E}{I}$$
$$= \frac{15}{.03}$$
$$= 500 \text{ ohms}$$

INFORMATION SHEET

V. Calculating conductance--Use the formula: $G = \frac{1}{R}$

EXAMPLE: A circuit has a resistance of 400 ohms. What is the conductance?

Solution: $G = \frac{1}{R}$

$G = \frac{1}{400}$

$G = .0025$ mhos

(NOTE: The above measurement may also be expressed as 2.5 millimhos.)

VI. Variables affecting conductor resistance

A. Cross-sectional area--Resistance decreases if cross-sectional area is increased

(NOTE: It is important to understand that one conductor with twice the diameter of another will have *four* times the cross sectional area and consequently will have *one-fourth* the resistance.)

B. Length--Resistance decreases if length is decreased

C. Resistivity--Various metals have different resistivities (Transparency #4)

D. Temperature--Resistance decreases as temperature decreases

(NOTE: In contrast to conductors, the temperature effect of transistor devices, electron tubes, and chemical batteries enhance rather than impede current flow.)

VII. Calculating electrical conductor resistance

A. Determine the cross-sectional area of the conductor in terms of circular mils

1. Convert the wire diameter to mils (Transparency #3)

a. Multiply inch measurements by 1,000

b. Multiply centimeter measurements by 393.7

c. Multiply millimeter measurements by 39.37

(NOTE: Tables found in the *National Electrical Code Handbook*, as well as many other electrical handbooks, list wire sizes by the American Wire Gauge [AWG] and give equivalent diameters in inches and mils.)

INFORMATION SHEET

2. Multiply the diameter--expressed in mils--by itself

   (NOTE: This will result in a cross-sectional area expressed as circular mils, which is not equivalent to the ordinary cross-sectional area expressed in square units.)

B. Determine conductor material restivity per mil foot (Transparency #4)

   (NOTE: These values can often be found in electrical handbooks.)

C. Calculate conductor resistance

   $R = \frac{KL}{A}$
   R = Resistance to be calculated
   K = Conductor resistivity per mil foot
   L = Total length of conductor
   A = Cross-sectional area expressed in circular mils

   EXAMPLE: An electrician wires a pushbutton switch at the plant entrance gate to a buzzer in the guard house 400 feet away. He uses AWG #10 aluminum wire. What is the conductor resistance of this circuit?

   Solution: $R = \frac{KL}{A}$

   K = 17 ohms per circular mil foot at 20°C (Transparency #4)

   L = 400 feet x 2 (wire must go to the button and return)

   = 800 feet

   A = Diameter x diameter (AWG #10 is 102 mils diameter [Transparency #3])

   = 102 x 102

   = 10,404 circular mils

   $R = \frac{17 \times 800}{10{,}404}$

   = 1.3 ohms

   Resistance = 1.3 ohms

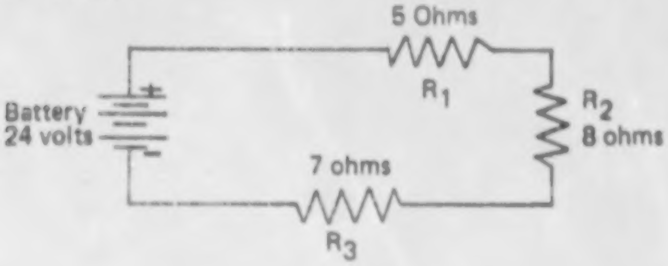
INFORMATION SHEET

VIII. Calculating the voltage across series resistors

A. Determine the total circuit resistance--Sum of the series of resistors

EXAMPLE: The circuit in Figure 2 has three resistors through which the electric current must flow in order to complete the path from one battery terminal to the other.

FIGURE 2



Total Resistance $= R_1 + R_2 + R_3$

$= 5 + 8 + 7$

$= 20$ ohms

B. Apply Ohm's Law to find the total current

EXAMPLE: The battery in the circuit in Figure 2 is 24 volts. The total resistance is 20 ohms as calculated above. These values are substituted into Ohm's Law below.

$$I = \frac{E}{R}$$

$$= \frac{24}{20}$$

$= 1.2$ amperes

C. Apply Ohm's Law to find the voltage of each resistor shown in Figure 2

EXAMPLE: $E = IR$

$E_{R_1} = 1.2 \times R_1$

$= 1.2 \times 5$

$= 6$ volts

Voltage across $R_1 = 6$ volts

INFORMATION SHEET

$E = IR$

$E_{R_2} = 1.2 \times R_2$

$= 1.2 \times 8$

$= 9.6$ volts

Voltage across $R_2 = 9.6$ volts

$E = IR$

$E_{R_3} = 1.2 \times R_3$

$= 1.2 \times 7$

$= 8.4$ volts

Voltage across $R_3 = 8.4$ volts

D. Using the individual resistor voltages, calculate the total voltage applied (Ea) by adding the individual voltage drops

EXAMPLE: $E_1 = 6$ volts

$E_2 = 9.6$ volts

$E_3 = 8.4$ volts

$Ea = E_1 + E_2 + E_3 ...$

$= 6 + 9.6 + 8.4$

$= 24$ volts

Total voltage applied = 24 volts

IX. Basic circuit characteristics

A. Series circuit (Transparency #5)

1. Same electrical current flows through every element
2. Voltage is divided among the elements in proportion to their resistance

B. Parallel circuit (Transparency #6)

1. Electrical current is divided among various branches in inverse proportion to their resistances
2. Voltage is same for all parallel branches

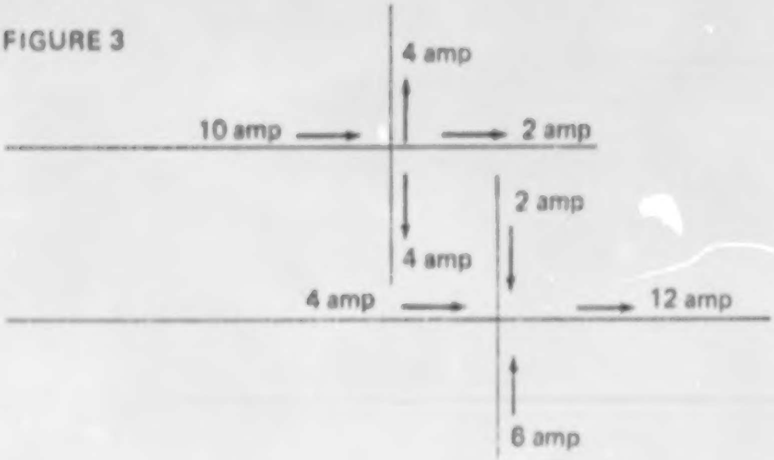
INFORMATION SHEET

X. Kirchoff's current and voltage laws

A. Current Law--The algebraic sum of the currents into any point of the circuit must equal the alegbraic sum of the currents out of that point (Figure 3)

EXAMPLE:

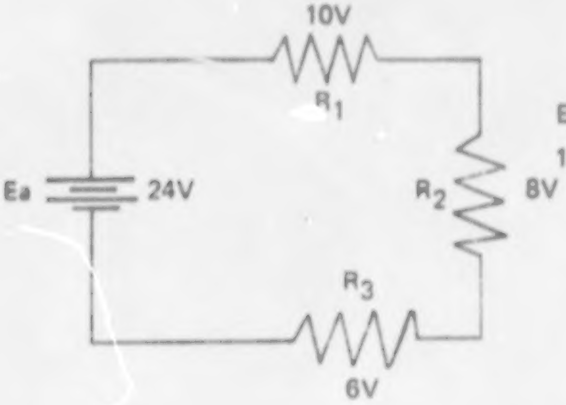
FIGURE 3


4 amp
10 amp
2 amp
2 amp
4 amp
4 amp
12 amp
6 amp

B. Voltage Law--The sum of the voltage drops around a closed loop must equal the voltage applied (Figure 4)

EXAMPLE:

FIGURE 4


10V
R1
Ea
24V
R2
8V
R3
6V

$E_{R_1}+E_{R_2}+E_{R_3}=Ea$

$10 + 8 + 6 = 24$ volts

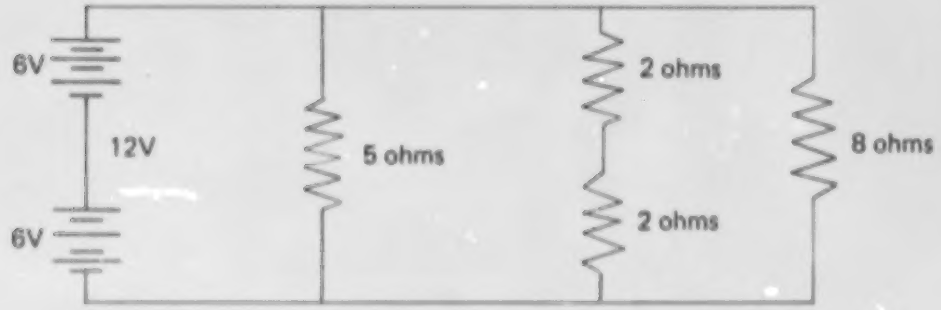
INFORMATION SHEET

XI. Calculating total current in a simple parallel circuit using Ohm's Law

A. Find the current in each branch

EXAMPLE: For the circuit in Figure 5, each element has 12 volts across it (E=12). Each resistance is known (R). Ohm's Law can be applied to each branch.

FIGURE 5



1. For the 5 ohm branch--

$I = \frac{E}{R}$

$= \frac{12}{5}$

= 2.4 amperes

Current = 2.4 amperes

2. For the 4 ohm branch--

$I = \frac{E}{R}$

$= \frac{12}{4}$

= 3 amperes

Current = 3 amperes

INFORMATION SHEET

3. For the 8 ohm branch--

$$I = \frac{E}{R}$$

$$= \frac{12}{8}$$

$$= 1.5 \text{ amperes}$$

Current = 1.5 amperes

B. Add branch currents together to get the total current

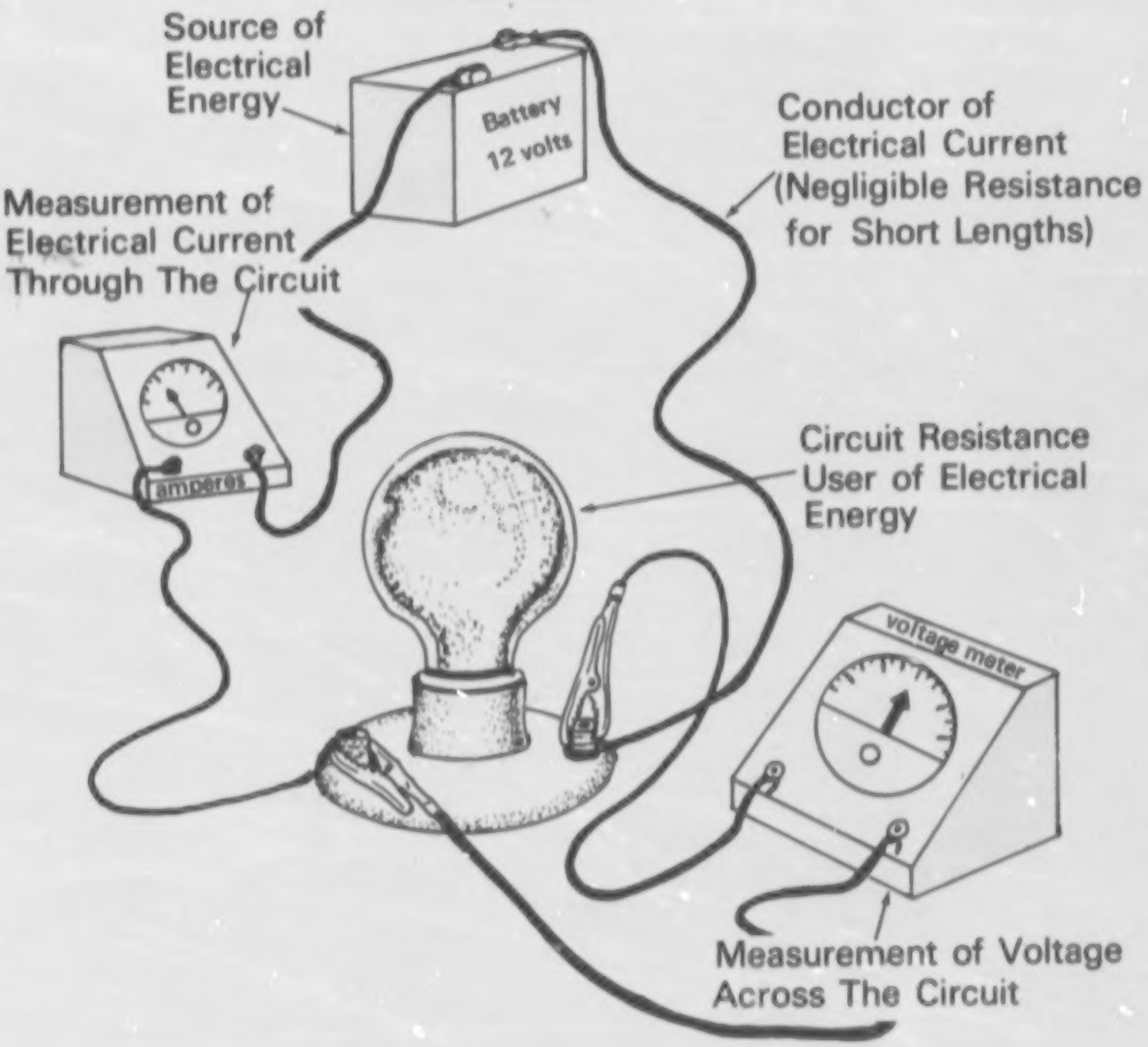
EXAMPLE: For the problem in Example XI A, the total current is 6.9 amperes.

$$I = 2.4 + 3 + 1.5$$

$$= 6.9 \text{ amperes}$$

Total current = 6.9 amperes

Basic Electrical Circuit



Source of Electrical Energy

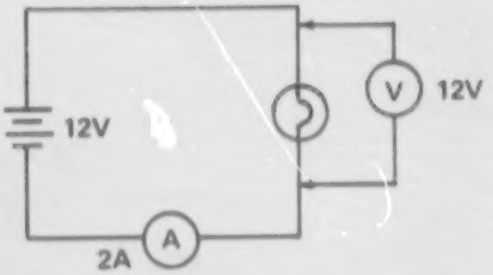
Conductor of Electrical Current (Negligible Resistance for Short Lengths)

Measurement of Electrical Current Through The Circuit

Circuit Resistance User of Electrical Energy

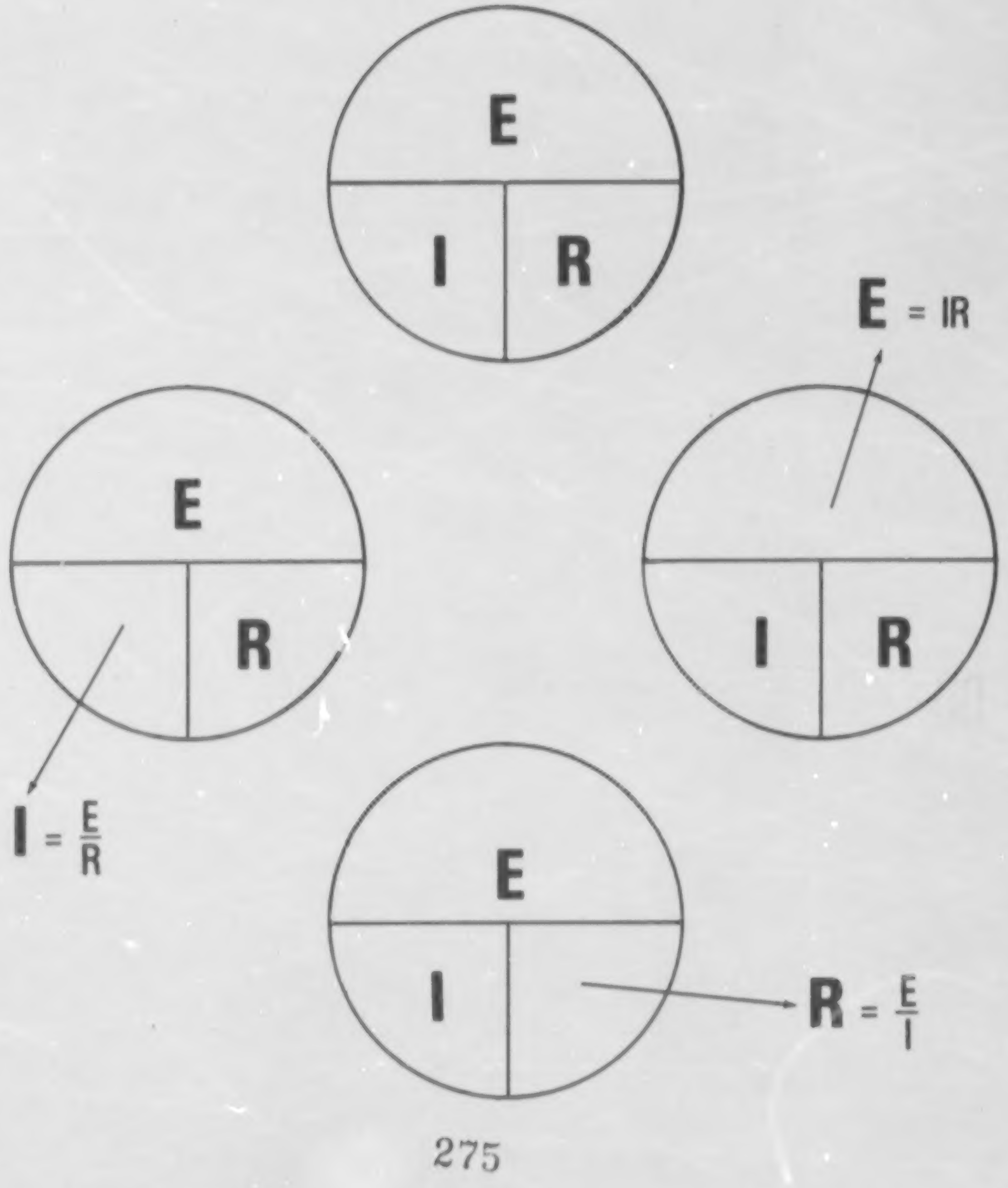
Measurement of Voltage Across The Circuit

Battery
12 volts
amperes
voltage meter



12V
V
12V
A
2A

Ohm's Law Memory Wheel


E
I
R
E = IR
E
R
I
R
I = E/R
E
I
R = E/I

American Wire Gage (AWG)

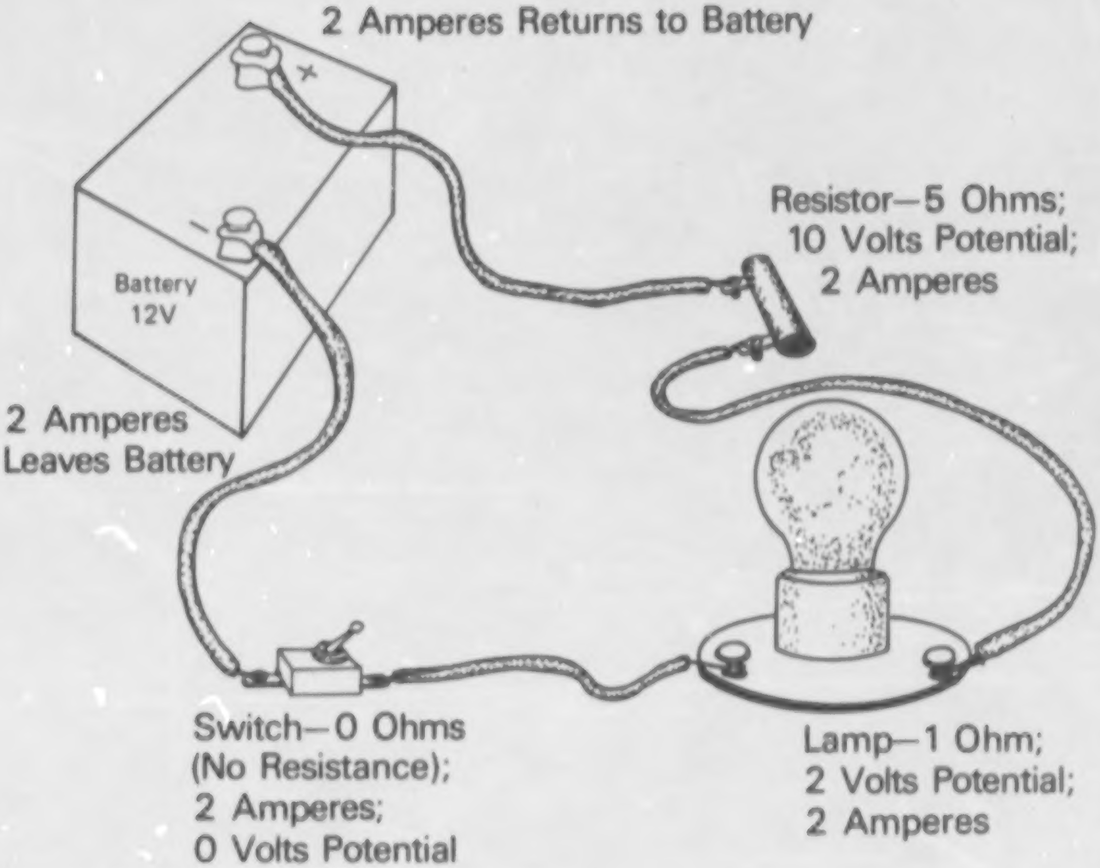
Brown and Sharpe Gauge Number	Diameter In Mills
#8	128
#9	114
#10	102
#11	91
#12	81
#13	72
#14	64
#15	57
#16	51
#17	45.3
#18	40.3
#19	35.9
#20	32.0
#21	28.5
#22	25.4
#23	22.6
#24	20.1

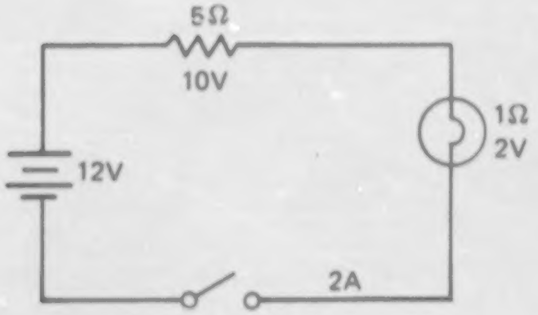
Conductor Resistivities

Ohms Per Circular Mil Foot at 20° C

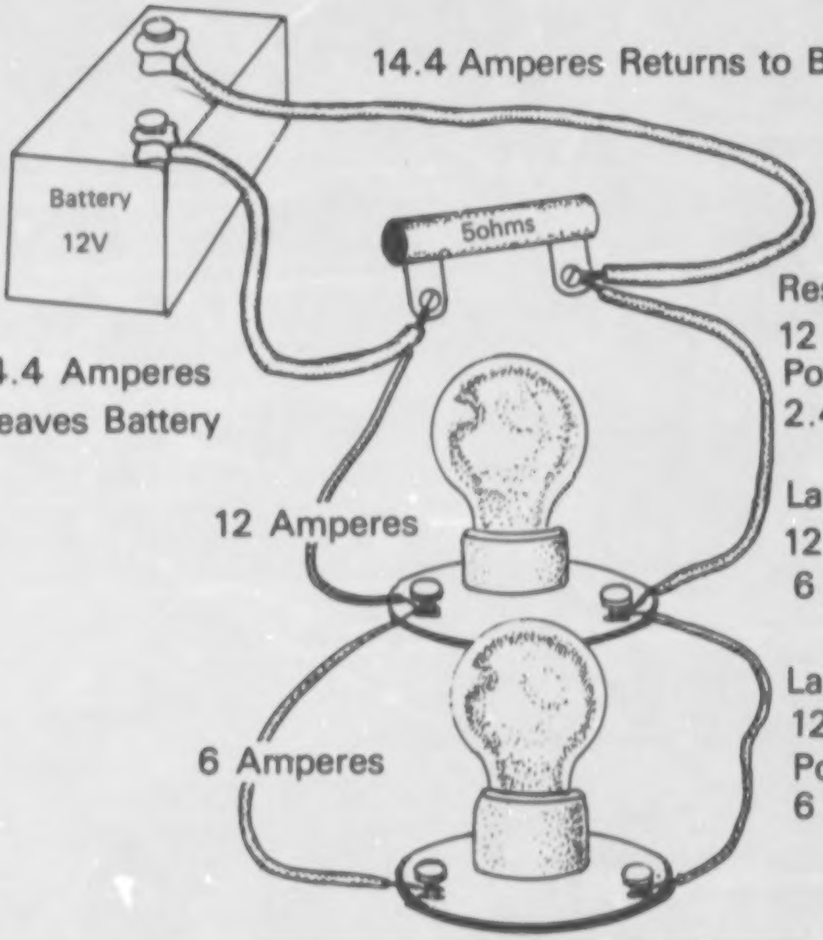
Material	Resistivity
Silver	9.56
Copper (annealed)	10.4
Aluminum	17
Tungsten	34
Brass	42
Nickle	60
Iron	61
Nichrome	675

Series Circuit


2 Amperes Returns to Battery
Battery
12V
2 Amperes
Leaves Battery
Resistor—5 Ohms;
10 Volts Potential;
2 Amperes
Switch—0 Ohms
(No Resistance);
2 Amperes;
0 Volts Potential
Lamp—1 Ohm;
2 Volts Potential;
2 Amperes


5Ω
10V
1Ω
2V
12V
2A

Parallel Circuit

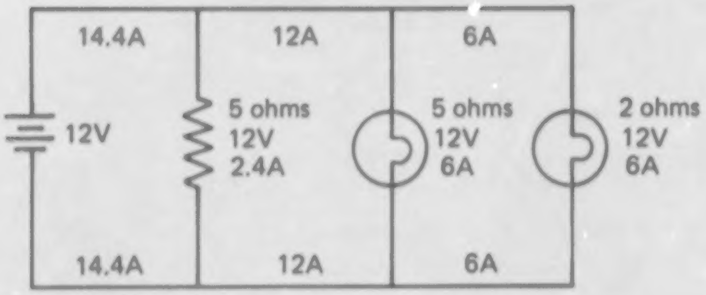

Battery
12V
5ohms
14.4 Amperes Leaves Battery
12 Amperes
6 Amperes

14.4 Amperes Returns to Battery

Resistor--5 Ohms;
12 Volts
Potential;
2.4 Amperes

Lamp--2 Ohms;
12 Volts Potential;
6 Amperes

Lamp--2 Ohms;
12 Volts
Potential;
6 Amperes


14.4A
12A
6A
12V
5 ohms
12V
2.4A
5 ohms
12V
6A
2 ohms
12V
6A
14.4A
12A
6A

DC FUNDAMENTALS
UNIT I

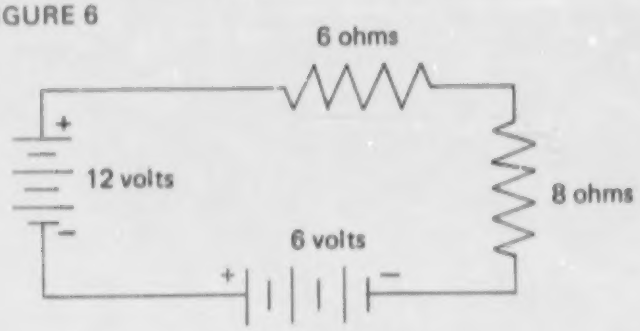
ASSIGNMENT SHEET #1--APPLY OHM'S LAW TO SERIES CIRCUITS WITH MULTIPLE COMPONENTS

NAME ____________________ SCORE ____________________

For a series circuit, the total resistance is simply the sum of all the resistors. The total voltage is the sum of all of the batteries, if they are all the same direction.

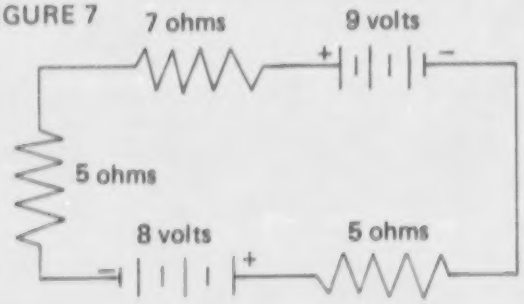
Find the indicated unknown in each of the following circuits (Figures 6-11)

1. FIGURE 6


6 ohms
+
12 volts
–
8 ohms
6 volts
+
–

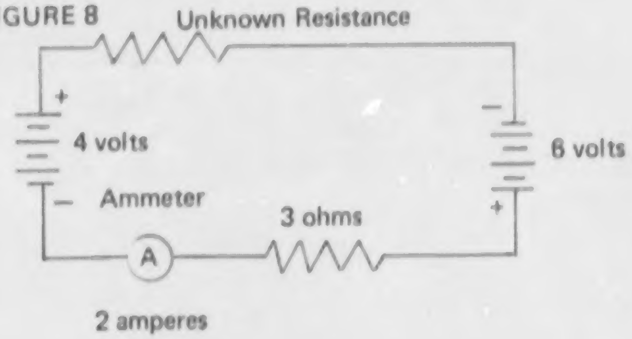
I= __________

2. FIGURE 7


7 ohms
9 volts
+
–
5 ohms
8 volts
+
5 ohms

I= __________

3. FIGURE 8

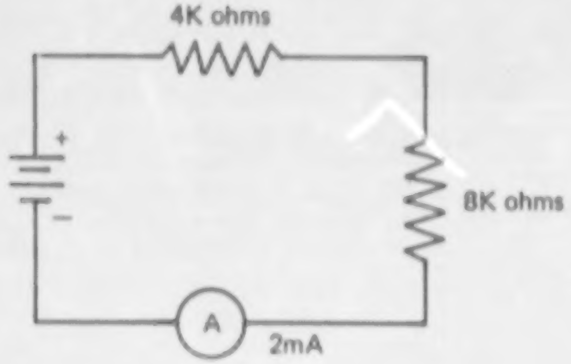

Unknown Resistance
+
4 volts
–
Ammeter
–
6 volts
+
3 ohms
A
2 amperes

If 2 amperes of current are flowing, what must be the value of the unknown resistor?

R_x= __________

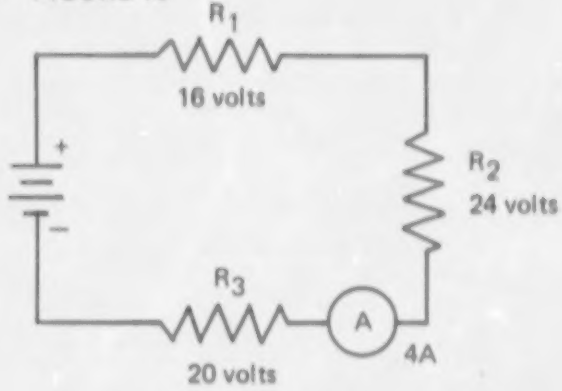
ASSIGNMENT SHEET #1

4. FIGURE 9


4K ohms
+
−
8K ohms
A
2mA

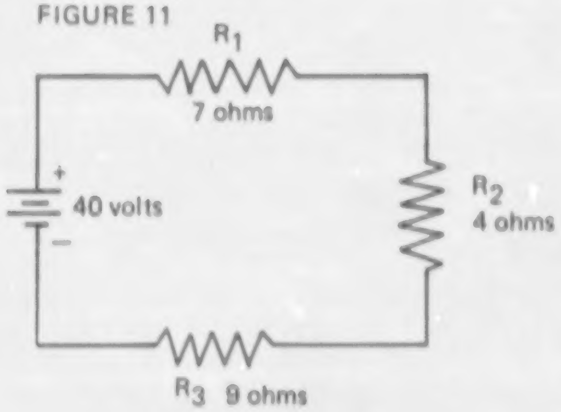
R_t=________________
Ea=________________

5. FIGURE 10


R_1
16 volts
+
−
R_2
24 volts
R_3
A
4A
20 volts

Ea=________________
R_1=________________
R_2=________________
R_3=________________
R_t=________________

6. FIGURE 11


R_1
7 ohms
+
40 volts
−
R_2
4 ohms
R_3 9 ohms

R_t=________________
I_t=________________
E_{R_1}=________________
E_{R_2}=________________
E_{R_3}=________________

DC FUNDAMENTALS
UNIT I

ASSIGNMENT SHEET #2--CALCULATE THE RESISTOR REQUIRED FOR A CONTROL RELAY CIRCUIT

NAME______________________________ SCORE ____________________

1. A control relay coil is designed to operate with 2 amperes of direct current. The coil resistance is 12 ohms. Applying Ohm's Law, what supply voltage should the coil have?

   ____

2. The control circuit above is modified to correct a design problem. The coil must now be attached to a 60 volt direct current supply. What total circuit resistance would result in 2 amperes of current flow? ________________________

3. What resistor size should be placed in series with the coil to make the total resistance as calculated in Step 2 above? ________________________

4. Sketch the resulting circuit.

DC FUNDAMENTALS
UNIT I

ASSIGNMENT SHEET #3--DETERMINE THE CORRECT INDICATIONS FOR A CONDUCTIVITY METER

NAME ______________________________ SCORE ____________________

Many industries employ instruments that measure "conductivity" of liquids as a means of monitoring consistency or quality of those liquids. Conductivity is also one of many measurements that may be used to determine the extent of pollutants in water discharged from industrial plants or water of lakes, rivers, and streams. Calculate conductivity readings for the instrument calibration resistors described below.

1. To check the instrument's accuracy near the low end of the measurement range, a 25 kilohm resistor is gauged. What should the meter indicate as a conductivity reading for this resistor? ______________________________

2. To check the meter operation at the high end of the scale, a 10 kilohm resistor is used. What should the meter indicate as a conductivity reading for this resistor? __________

   ____

DC FUNDAMENTALS
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. 1.28 amperes
2. 1.0 amperes
3. 2 ohms
4. 12 Kohms

   24 volts
5. 60 volts

   4 ohms

   6 ohms

   5 ohms

   15 ohms
6. 20 ohms

   2 amps

   14 volts

   8 volts

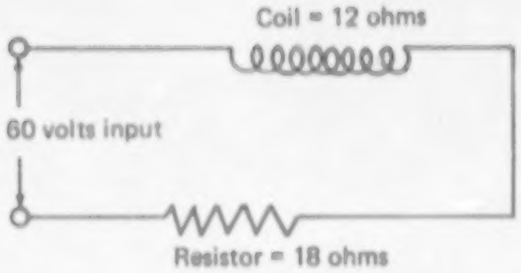
   18 volts

Assignment Sheet #2

1. 24 volts
2. 30 ohms
3. 18 ohms

ANSWERS TO ASSIGNMENT SHEETS

4.


Coil = 12 ohms
60 volts input
Resistor = 18 ohms

Assignment Sheet #3

1. .00004 mhos

   (or 40 micromhos)

2. .0001 mhos

   (or .1 millimhos)

DC FUNDAMENTALS
UNIT I

JOB SHEET #1--CONSTRUCT A SERIES DIRECT CURRENT CIRCUIT HAVING A PREDETERMINED ELECTRICAL CURRENT FLOW

I. Equipment and materials

  A. Resistors--3 totaling between 1,000 and 10,000 ohms

  B. Test leads--5 of appropriate length with connectors which accommodate the equipment being used

  C. Direct current power supply--Output capability of 12-60 volts; current capacity of at least 60 milliamperes (mA)

  (NOTE: A battery may be used in leiu of a suitable DC power supply.)

  D. Ammeter or multimeter--Capable of measuring to within 10 milliamperes (mA)

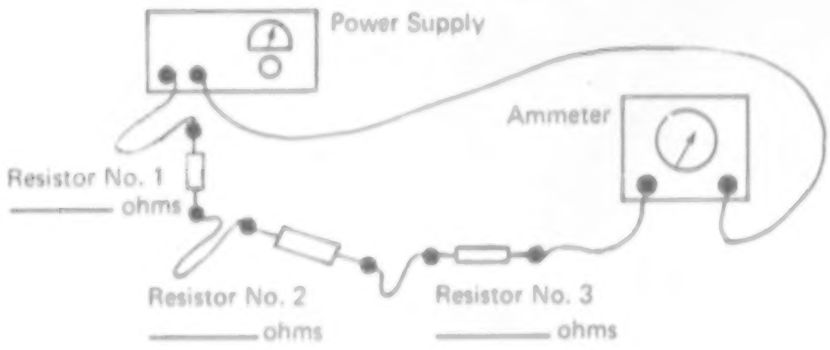
  (NOTE: If the power supply is capable of supplying more current than the minimum 60 milliamperes specified above, then it may be possible to reduce the size of the resistors to between 100 and 1000 ohms. This will permit a less sensitive ammeter to be used effectively. The instructor must determine which resistor sizes are best suited for the power supply and ammeter to be used.)

II. Procedure

  A. In the spaces provided in Figure 12, record the values of the three resistors supplied to you by your instructor

  B. Calculate the total amperage for the circuit at the voltage specified by your instructor; record the amperage in the space provided in Figure 12

FIGURE 12



Total resistance of the circuit is ____________ ohms

Amperage for the circuit will be ____________ amperes

Measured Amperage ____________ amperes

JOB SHEET #1

C. Connect the three resistors and the ammeter as shown in Figure 12

(NOTE: Do not connect the power supply at this time.)

D. Turn the power supply on and adjust the output voltage to the value specified by your instructor

E. Select the ammeter settings specified by your instructor

(NOTE: Have the instructor check your calculations, your circuit arrangement, and your ammeter settings, as well as your power supply output.)

F. Turn the power supply off

G. Connect circuit to power supply

H. Turn power supply on

I. Make fine adjustments to the output voltage to get the exact value specified

J. Record the ammeter indication in the space provided in Figure 12

K. Compare the ammeter indication to the value calculated

(NOTE: Show your results to the instructor.)

L. Put equipment and materials away

DC FUNDAMENTALS
UNIT I

JOB SHEET #2--CONSTRUCT A PARALLEL DIRECT CURRENT CIRCUIT HAVING A PREDETERMINED ELECTRICAL CURRENT FLOW

I. Equipment and materials

A. Resistors--3 with at least 5,000 ohms each but not more than 25,000 ohms

B. Test leads--7 of appropriate length with connectors which will accommodate the equipment being used

C. Direct current power supply--Output capability of 12-60 volts, and current capacity of at least 60 milliamperes (mA)

(NOTE: A battery may be used in lieu of a suitable DC power supply.)

D. Ammeter or multimeter--Capable of measuring to within 10 milliamperes (mA)

(NOTE: If the power supply is capable of supplying more current than the minimum 60 milliamperes specified above, then it may be possible to reduce the size of the resistors to between 500 and 2,500 ohms. This will permit a less sensitive ammeter to be used effectively. The instructor must determine which resistor sizes are best suited for the power supply and ammeter to be used.)

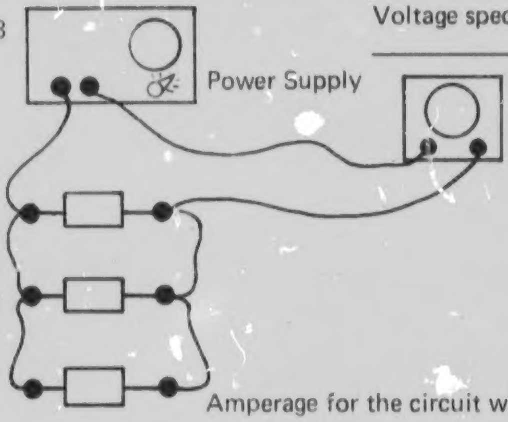
II. Procedure

A. In the spaces provided in Figure 13, record the values of the three resistors supplied to you by your instructor

JOB SHEET #2

B. Calculate the total amperage for the circuit at the voltage specified by your instructor; record the amperage in the space provided in Figure 13

FIGURE 13



Voltage specified by instructor: ________________ volts

Resistor No. 1

________ ohms

Resistor No. 2

________ Ohms

Resistor No. 3

_______ ohms

Amperage for the circuit will be___________amperes

Measured Amperage_________amperes

C. Connect the three resistors and the ammeter as shown in Figure 13

(NOTE: Do not connect the power supply at this time.)

D. Turn the power supply on and adjust the output voltage to the value specified by your instructor

E. Select the ammeter settings specified by your instructor

(NOTE: Have your instructor check your calculations, your circuit arrangement, and your ammeter settings, as well as your power supply output.)

F. Turn the power supply off

G. Connect circuit to power supply

H. Turn power supply on

I. Make fine adjustments to the output voltage to get the exact value specified

J. Record ammeter indication in the space provided in Figure 13

K. Compare the ammeter indication to the value calculated

(NOTE: Show your results to the instructor.)

L. Put equipment and material away

DC FUNDAMENTALS
UNIT I

JOB SHEET #3--USE A RESISTOR TO REDUCE VOLTAGE

I. Equipment and materials

A. Variable resistor (potentiometer or reheostat)--Value variable between zero and a maximum 100-500 ohms

B. Low voltage direct current relay--Coil voltage of 24 volts or less

(NOTE: The device must be of the open relay type having visible contacts, or it must be possible to hear it function so that its operation can be monitored. Also, the instructor may want to wire an indicator lamp to the relay contacts to clearly show the relay operation. The relay would then not have to be of the open type or be audible.)

C. Test leads--3 of 8 cm (3.15 inches)-75 cm (29.53 inches), having connectors suitable for equipment being used

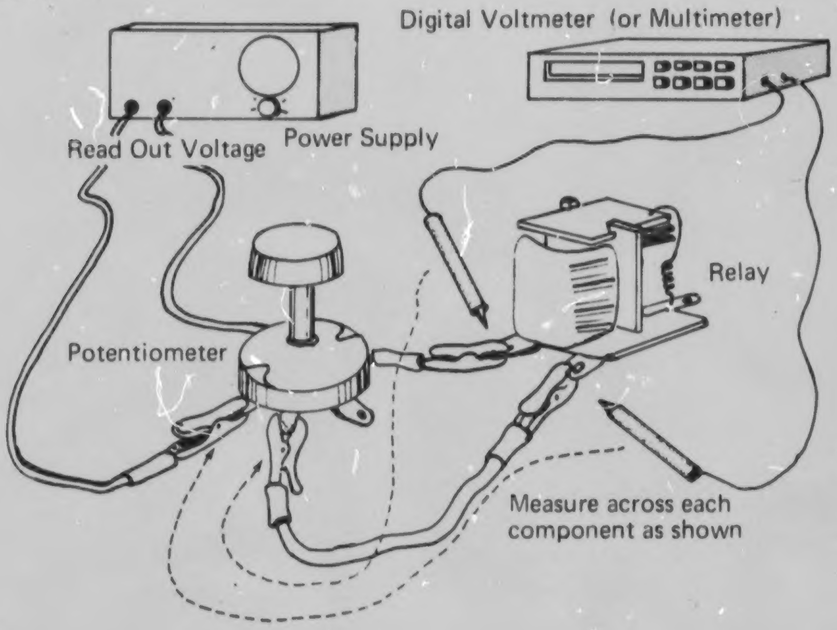
D. Direct current power supply--Capable of producing 36 volts or more at an amperage at least equivalent to that required by the relay specified above

E. Voltmeter (multimeter or volt-ohm meter [VOM]), with test leads

II. Procedure

A. Connect the relay and potentiometer in series (Figure 14)

FIGURE 14


Digital Voltmeter (or Multimeter)
Read Out Voltage
Power Supply
Relay
Potentiometer
Measure across each component as shown

JOB SHEET #3

B. Turn the potentiometer to the highest resistance setting

(NOTE: Ask your instructor for assistance if you are not sure of the setting.)

C. Turn on the power supply

D. Adjust the output voltage to 1 1/2 times the voltage of the relay

(NOTE: Adjust for a 24-volt relay by setting the power supply to 36 volts. Have the instructor check your power supply output adjustment and your circuit.)

E. Turn the power supply off

F. Connect circuit to power supply

G. Turn on power supply

H. Make fine adjustments to the output voltage to get the exact value specified

I. Check the state of the relay

(NOTE: If relay is activited [pulled in], then the resistor is not adjusted to the maximum or the relay is particularly sensitive. For a sensitive relay, reduce the power supply output until the relay releases, then reduce the output an additional four volts.)

J. Set the voltmeter controls to those specified by the instructor, and measure the voltage across both the resistor and the relay coil as shown in Figure 14

1. Resistor voltage = ______________________________
2. Relay coil voltage = ______________________________
3. Power supply voltage = ______________________________

K. Slowly reduce the resistor value until the relay activates and remains stable

L. Again measure the voltage across both the resistor and the relay coil

1. Resistor voltage = ______________________________
2. Relay coil voltage = ______________________________
3. Power supply voltage = ______________________________

JOB SHEET #3

M. Answer the following questions

1. Does the sum of the relay voltage and the coil voltage equal the power supply voltage in both cases?

   ____

2. In step K, which component has the highest voltage?

   ____

3. In step M, which component has the highest voltage?

   ____

4. If the voltage in a simple control circuit is too high for a component, how may it be corrected?

   ____

   ____

5. Would the resistor in this circuit work to reduce the relay's voltage if it were in parallel instead of in series?

   ____

   (NOTE: Show your measurements and answers to the instructor.)

N. Put equipment and materials away

DC FUNDAMENTALS
UNIT I

TEST

NAME ______________________________ SCORE ____________________

1. Match terms associated with direct current fundamentals to the correct definitions. Write the correct numbers in the blanks.

_____a. Measurement unit for the resistance to electrical current offered by a circuit or device

_____b. Measurement unit for conductance of a device or circuit

_____c. Measurement unit for a quantity of electrons; electricity; electrical current; current flow

_____d. Area contained in a circle having a diameter of one mil

_____e. One-thousandth of an inch or .001 inches

_____f. Device used to impede electrical current flow or to divide voltages within circuits

_____g. Electrical current that moves consistently in only one direction

_____h. Specific resistance of materials expressed as ohms per circular mil foot

_____i. Mathematical inverse of resistance

_____j. Measurement unit for electrical potential or electrical force; electromotive force (emf)

_____k. Circuit in which electric current has only one path throughout

_____l. Specific conductance of materials; mathematical inverse of resistivity

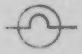
_____m. Movement of electrons through conductor

1. Amperage
2. Voltage
3. Ohm
4. Resistor
5. Resistivity
6. Conductivity
7. Mho
8. Direct current
9. Series circuit
10. Mil
11. Circular mil
12. Conductance
13. Current

TEST

2. Name direct current abbreviations and symbols given below by writing the correct answer in the blanks. Some abbreviations and symbols may have more than one name.

A. R_t ____________________

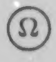
B.  ____________________

C. R ____________________

D. I ____________________

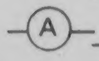
E. Ω ____________________

F. G ____________________

G.  ____________________

H. Ea ____________________

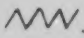
I. DC ____________________

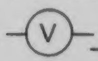
J.  ____________________

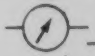
K. I_t ____________________

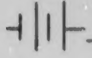
L. A ____________________

M. emf ____________________

N.  ____________________

O.  ____________________

P.  ____________________

Q.  ____________________

R. V ____________________

3. State Ohm's Law according to the given instructions.

a. Statement of circuit behavior-- ____________________

____

b. Mathematical formula for current-- ____________________

____

c. Mathematical formula for voltage-- ____________________

____

d. Mathematical formula for resistance-- ____________________

____

TEST

4. Calculate electrical properties by using Ohm's Law in each of the following problems.

   a. If a circuit that measures 20 ohms is connected across a 12-volt battery, what current will flow?

   Current = ____________________

   b. An electric lamp has a resistance of 14 ohms and requires 2 amperes of current flowing through it in order to produce its intended amount of light. What voltage should it be connected to in order to operate properly?

   Voltage = ____________________

   c. An electrician measures 20 amperes in the supply line to an electric heater. It is connected across a 400-volt direct current power source. What is the resistance of the heater?

   Resistance = ____________________

5. Calculate conductance in the problem below.

   A sample of material has a resistance of 2,000 ohms. What is the conductance of the sample?

   Conductance = ____________________

TEST

6. State how variables affect conductor resistance.

   a. Cross-sectional area-- ____________________

   b. Length-- ____________________

   c. Resistivity-- ____________________

   d. Temperature-- ____________________

7. Calculate electrical conductor resistance in the problem below.

   Using the table of wire diameters in mils, the diameter of a AWG #12 wire is found to be 81 mils. The resistivity of the wire is 20.0 ohms per circular mil foot, and the length of the wire is 324 feet. Use the formula below to find the wire's resistance.

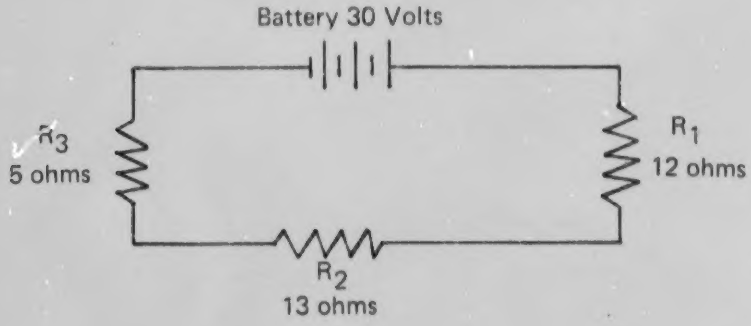
$$R = \frac{KL}{A}$$

   R = Resistance of the wire
   K = Ohms per circular milfoot
   A = Cross-sectional area in circular mils
   L = Length of the wire in feet

   (NOTE: *A* in the formula is not equal to the diameter.)

   Wire's resistance = ____________________

8. Calculate the voltage across series resistors in the problem below.



E_{R_1} = ____________ E_{R_2} = ____________ E_{R_3} = ____________

TEST

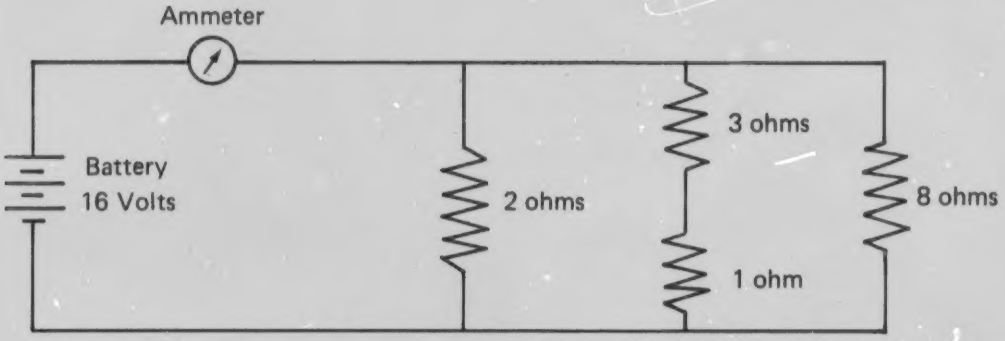
9. Describe the basic circuit characteristics in series and parallel circuits.

10. State Kirchoff's current and voltage laws.

    a. Current Law--

    b. Voltage Law--

11. Calculate total current in the simple parallel circuit using Ohm's Law in the problem below.


Ammeter
Battery
16 Volts
2 ohms
3 ohms
1 ohm
8 ohms

TEST

(NOTE: Test questions 12-15 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

12. Apply Ohm's Law to series circuits with multiple components.

13. Calculate the resistor required for a control relay circuit.

14. Determine the correct indications for a conductivity meter.

15. Demonstrate the ability to

    a. Construct a series direct current circuit having a predetermined electrical current flow.

    b. Construct a parallel direct current circuit having a predetermined electrical current flow.

    c. Use a resistor to reduce voltage.

DC FUNDAMENTALS
UNIT I

ANSWERS TO TEST

1. a. 3
   b. 7
   c. 1
   d. 11
   e. 10
   f. 4
   g. 8
   h. 5
   i. 12
   j. 2
   k. 9
   l. 6
   m. 13

2. a. Resistance total
   b. Light
   c. Resistor
   d. Current
   e. Ohm
   f. Conductance
   g. Ohmmeter
   h. Voltage applied
   i. Director current
   j. Ammeter
   k. Current total
   l. Amperage, amp
   m. Electromotive force
   n. Resistor
   o. Voltmeter
   p. Meter
   q. Battery
   r. Voltage, volt

3 a. Amperage through a circuit equals the voltage across the circuit divided by the resistance in the circuit
   b. $I = \frac{E}{R}$
   c. $E = IR$
   d. $R = \frac{E}{I}$

4. a. 0.6 amperes
   b. 28 volts
   c. 20 ohms

ANSWERS TO TEST

5. 0.5 millimhos or 0.0005 mhos

6. a. Resistance decreases if cross-sectional area is increased

   b. Resistance decreases if length is decreased

   c. Various metals have different restivities

   d. Resistance decreases as temperature decreases

7. 1 ohm

8. a. 12 volts

   b. 13 volts

   c. 5 volts

9. a. Series circuit

      1. Same electrical current flows through every element

      2. Voltage is divided among the elements in proportion to their resistance

   b. Parallel circuit

      1. Electrical current is divided among various branches in inverse proportion to their resistances

      2. Voltage is same for all parallel branches

10. a. The algebraic sum of the currents into any point of the circuit must equal the algebraic sum of the currents out of that point

    b. The sum of the voltage drops around a closed loop must equal the voltage applied

11. 14 amperes

12. Evaluated to satisfaction of instructor

13. Evaluated to satisfaction of instructor

14. Evaluated to satisfaction of instructor

15. Performance skills evaluated to satisfaction of instructor

SERIES-PARALLEL CIRCUITS
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to apply Ohm's Law and Kirchoff's laws of current and voltage to series-parallel circuits to verify calculated values. The student should also be able to locate troubles by making electrical measurements. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms assocated with series-parallel circuits to their correct definitions.
2. Match abbreviations and symbols associated with series-parallel to their correct definitions.
3. Distinguish between the characteristics of series circuits and parallel circuits.
4. Calculate total resistance in a simple series-parallel circuit.
5. Calculate current and voltage using Ohm's Law and Kirchoff's laws of voltage and current.
6. Determine voltages available in unloaded and loaded voltage dividers.
7. Determine circuit characteristics when components are open or shorted.
8. Calculate equivalent resistance of resistors in series-parallel.
9. Calculate circuit values of series-parallel components.
10. Demonstrate the ability to
    a. Measure resistance in a series-parallel circuit.
    b. Measure current in a series-parallel circuit.
    c. Measure voltage in a series-parallel circuit.
    d. Analyze loaded and unloaded voltage dividers.
    e. Troubleshoot series-parallel circuits.

SERIES-PARALLEL CIRCUITS
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Demonstrate voltage dividers by showing how voltage and current is affected by varying the circuit's components.

   H. Give test.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency masters

      1. TM #1--Resistive Circuits

      2. TM #2--Unloaded Voltage Divider

      3. TM #3--Loaded Voltage Divider

      4. TM #4--Series Circuit Without Problems

      5. TM #5--Series Circuit with Open

      6. TM #6--Series Circuit with Short

   E. Assignment sheets

      1. Assignment Sheet #1--Calculate Equivalent Resistance of Resistors in Series-Parallel

      2. Assignment Sheet #2--Calculate Circuit Values of Series-Parallel Components

SUGGESTED ACTIVITIES

   3. Assignment Sheet #3--Calculate Voltages Available in Unloaded and Loaded Voltage Dividers

F. Answers to assignment sheets

G. Job sheets

   1. Job Sheet #1--Measure Resistance in a Series-Parallel Circuit
   2. Job Sheet #2--Measure Current in a Series-Parallel Circuit
   3. Job Sheet #3--Measure Voltage in a Series-Parallel Circuit
   4. Job Sheet #4--Analyze Loaded and Unloaded Voltage Dividers
   5. Job Sheet #5--Troubleshoot Series-Parallel Circuits

H. Test

I. Answers to test

III. Unit references

A. Grob, Bernard. *Basic Electronics.* 4th ed. New York: McGraw-Hill Book Company, 1977.

B. Shrader, Robert L. *Electronic Communication.* 3rd ed. New York: McGraw-Hill Book Company, 1975.

SERIES-PARALLEL CIRCUITS
UNIT II

INFORMATION SHEET

I. Terms and defintions

   A. Series--Components connecting end-to-end in a circuit to provide a single path for current flow

   B. Parallel--Components connecting to the same pair of terminals so that current must take more than one path

   C. Series-parallel--Components connectng both end-to-end and to the same terminals, combining both the series circuit and the parallel circuit

   D. Open--Circuit interruption that results in an incomplete path for current flow

   E. Voltage divider--Resistance connected across a voltage source where only a portion of the voltage is tapped off

   F. Load--Resistance connected to a voltage source which consumes power

   G. Reference point--Common point in a circuit

      (NOTE: Reference point is often referred to as a *ground point.*)

   H. Parameter--Determinant, such as voltage, frequency, and component values, that determines other characteristics of the circuit

   I. Potential difference--Difference of voltage between one end of an electronic component and the other end

   J. Galvanometer--Very sensitive meter for measuring small values of current, both in the positive and negative direction

   K. Wheatstone bridge--Instrument used to measure unknown resistance values

   L. Short--Abnormal, relatively low resistance connection between two points of a circuit

II. Abbreviations and symbols associated with series-parallel

   A. A--Amperage; amp

   B. V--Voltage; volt

   C. DC--Direct current

   D. AC--Alternating current

   E. Ω--Ohm

   F. N--Number (of components)

INFORMATION SHEET

G. **Gnd**--Ground

H. **K**--Kilo

I. **Kohm**--Kilohm

J. **R**--Resistor; resistance

K. **I**--Current

L. **E_R**--Resistor voltage

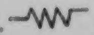
M. **I_R**--Resistor current

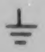
N. **R_e**--Equivalent resistance

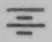
O. **R_t**--Total resistance

P. **I_t**--Total current

Q. **E_a**--Voltage applied

R.  --Resistor symbol

S.  --Ground symbol

T.  --Battery symbol

III. Characteristics of series and parallel circuits

A. Series circuits (Transparency #1)

1. All components are connected end-to-end
2. Total resistance is equal to the sum of all resistances
3. Current is equal throughout the circuit
4. The sum of the individual voltage drops equal to the voltage applied

B. Parallel circuits (Transparency #1)

1. Components are connected side-by-side in the same pair of terminals
2. Total resistance may be calculated using one of the resistance formulas for parallel circuits:

   a. $R_t = \frac{R_1 \times R_2}{R_1 + R_2}$

   b. $R_t = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots}$

   c. $R_t = \frac{R}{N}$

INFORMATION SHEET

3. Current divides into each branch dependent upon the resistance

4. Voltage is equal through parallel branches

   (NOTE: Characteristics of both series and parallel circuits must be observed for series-parallel circuits. See Transparency #1.)

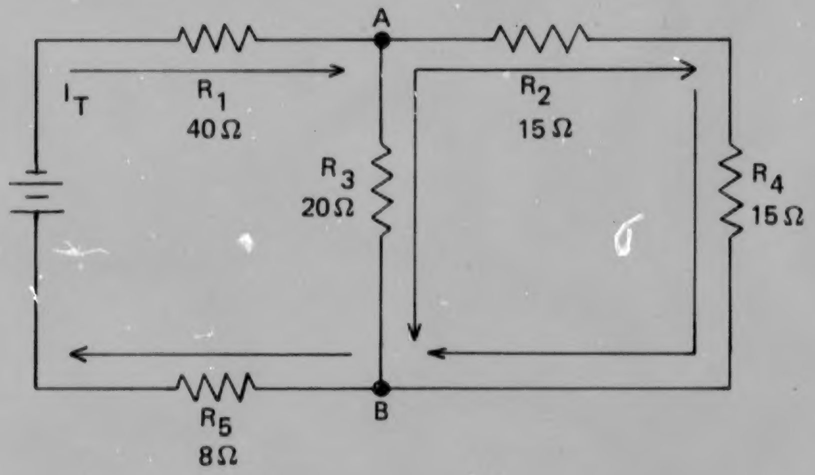
IV. Calculating total resistance in a series-parallel circuit (Figures 1-5)

A. Determine which components are in series and which are in parallel

B. Calculate resistance using the resistance formulas

EXAMPLE: Series-parallel circuit

FIGURE 1



1. Following a path for current flow from the negative side of the battery, total current will flow through R_1

2. At point A, current will divide between R_2 and R_3

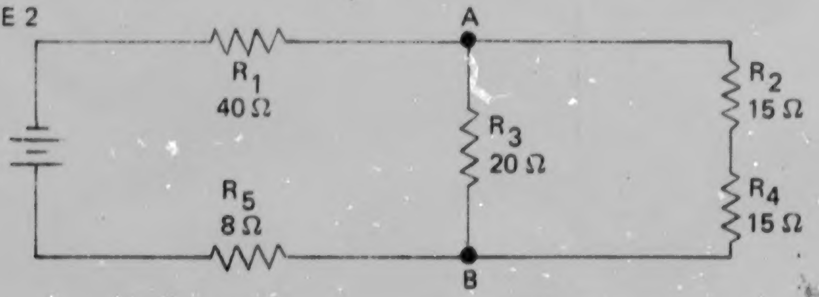
   (NOTE: This is a *parallel path.*)

INFORMATION SHEET

3. Current flowing through R_2 also will flow through R_4, which is in series with R_2 only

EXAMPLE:

FIGURE 2

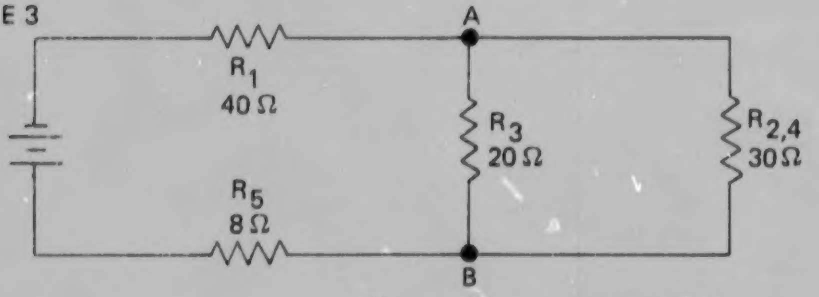

A
R_1
40 Ω
R_3
20 Ω
R_2
15 Ω
R_5
8 Ω
R_4
15 Ω
B

4. Parallel currents of R_4 and R_3 come together at point B

(NOTE: R_2 and R_4 are in parallel with R_3.)

EXAMPLE:

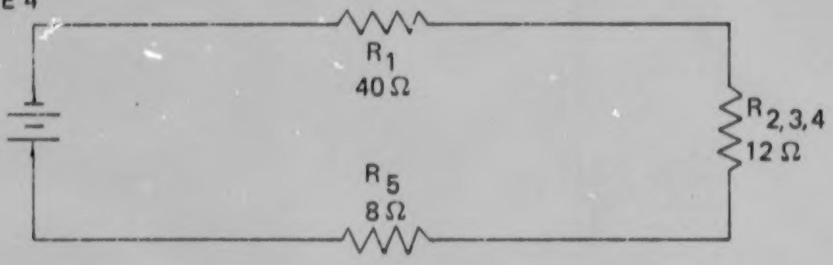
FIGURE 3


A
R_1
40 Ω
R_3
20 Ω
$R_{2,4}$
30 Ω
R_5
8 Ω
B

5. Total current will flow through R_5, which is in series with R_1 and R_2, R_3 and R_4

EXAMPLE:

FIGURE 4

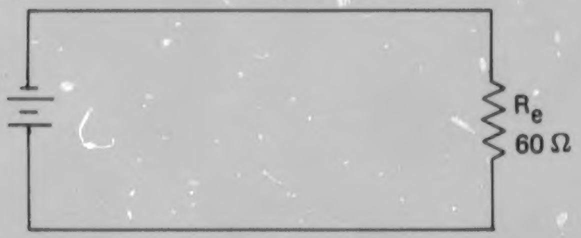

R_1
40 Ω
$R_{2,3,4}$
12 Ω
R_5
8 Ω

INFORMATION SHEET

6. Total circuit can then be redrawn as one resistor for equivalent total resistance

   EXAMPLE:

FIGURE 5



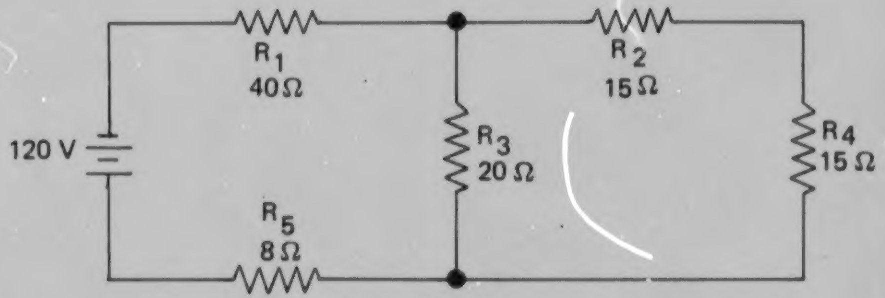
V. Calculating current and voltage using Ohm's Law and Kirchoff's laws of voltage and current (Assignment Sheet #2; Figures 6-8)

(NOTE: Using the same examples as in Objective III, it has been determined that equivalent resistance is 60 ohms.)

A. Calculate total current using Ohm's Law; use the formula $I_t = \frac{E_a}{R_e}$

EXAMPLE: Use an applied voltage of 120 volts

FIGURE 6



Solution: $I_t = \frac{E_a}{R_e}$

$= \frac{120\ V}{60\ \Omega}$

$= 2\ A$

INFORMATION SHEET

B. Calculate voltage drops of the individual resistors

(NOTE: Since R_1 and R_5 are series resistors, total current will flow through these components.)

1. Calculate for the voltage drop through R_1; use the formula $E_{R_1} = I_{R_1} \times R_1$

   EXAMPLE: $E_{R_1} = I_{R_1} \times R_1$

   $= 2\ A \times 40\ \Omega$

   $= 80\ V$

2. Calculate for the voltage drop through R_5; use the formula $E_{R_5} = I_{R_5} \times R_5$

   EXAMPLE: $E_{R_5} = I_{R_5} \times R_5$

   $= 2\ A \times 8\ \Omega$

   $= 16\ V$

   (NOTE: Voltage drops of R_1 and R_5 leave 24 volts to be felt through the series branches of R_2, R_3 and R_4. Kirchoff's Law of Voltage states that "the sum of the voltage drops around a closed loop, equal the voltage applied.")

   EXAMPLE:

FIGURE 7

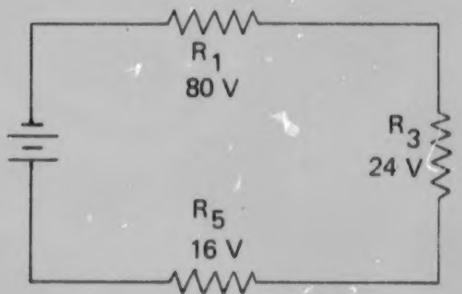
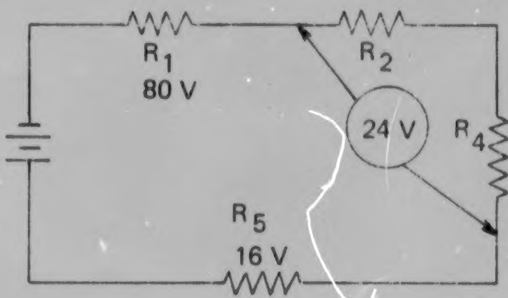


FIGURE 8



INFORMATION SHEET

C. Calculate the parallel current values

(NOTE: Once voltage in each parallel branch circuit has been determined, current for each branch can be calculated and individual voltage drops determined. Kirchoff's Law of Current states that "the sum of the currents entering a point must equal the sum of the currents leaving that point.")

1. Calculate current through R_3; use the formula $I_{R_3} = \frac{E_{R_3}}{R_3}$

EXAMPLE: $I_{R_3} = \frac{E_{R_3}}{R_3}$

$= \frac{24\ V}{20\ \Omega}$

$= 1.2\ A$

2. Calculate the current through R_2 and R_4; use the formula $I_{R_{2,4}} = \frac{E_{R_{2,4}}}{R_{2,4}}$

EXAMPLE: $I_{R_{2,4}} = \frac{E_{R_{2,4}}}{R_{2,4}}$

$= \frac{24\ V}{30\ \Omega}$

$= .8\ A$

D. Calculate the voltage drops of resistors R_2, R_3, and R_4

(NOTE: By using the current values calculated in step C, individual voltages may be found for R_2 and R_4.)

1. Calculate the voltage drop through R_2; use the formula $E_{R_2} = I_{R_2} \times R_2$

EXAMPLE: $E_{R_2} = I_{R_2} \times R_2$

$= .8\ A \times 15\ \Omega$

$= 12\ V$

2. Calculate the voltage drop through R_4; use the formula $E_{R_4} = I_{R_4} \times R_4$

EXAMPLE: $E_{R_4} = I_{R_4} \times R_4$

$= .8\ A \times 15\ \Omega$

$= 12\ V$

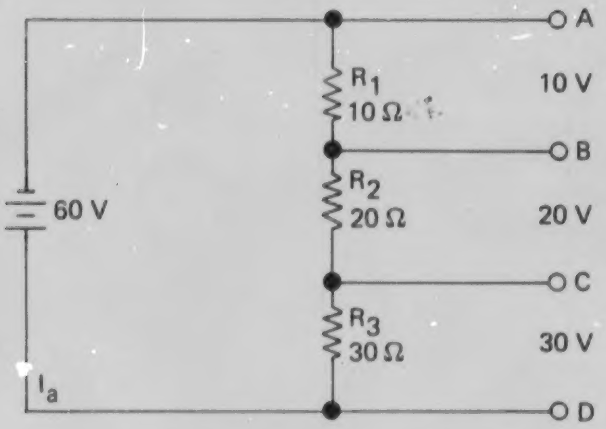
(NOTE: Resistance values of R_2 and R_4 were equal, which indicates that they will have an equal voltage drop.)

INFORMATION SHEET

VI. Determine voltages available in unloaded and loaded voltage dividers (Assignment Sheet #3; Figures 9 and 10)

A. Unloaded voltage dividers--In a series resistive circuit with a variety of available voltages, voltages are determined by using series circuit characteristics. (Transparency #2)

FIGURE 9



1. Point A with reference to point D = -60 V
2. Point B with reference to point D = -50 V
3. Point C with reference to point D = -30 V
4. Point A with reference to point B = -10 V
5. Point C with reference to point B = +20 V
6. Point D with reference to point B = +50 V

(NOTE: By using various reference points, various voltages are given or can be determined. If the voltage measurement point is closer to the positive pole of the power source, voltage is positive. If the voltage measurement point is closer to the negative pole of the power source, voltage is negative.)

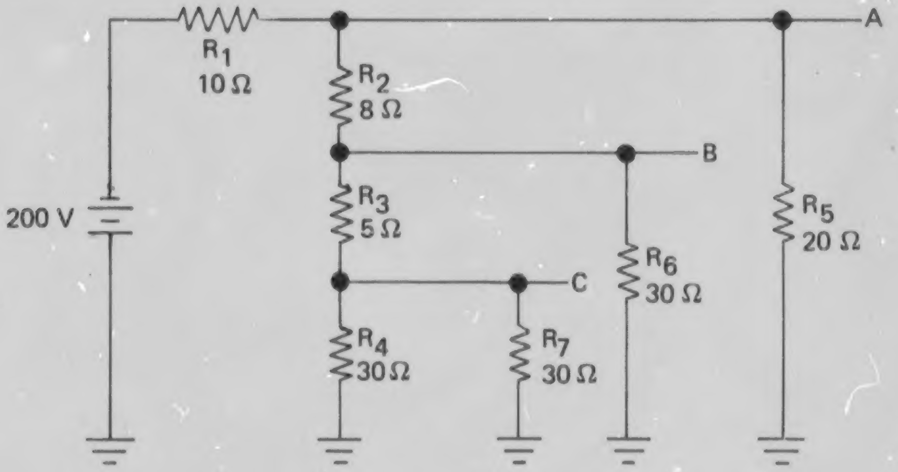
INFORMATION SHEET

B. Loaded voltage divider--In a series resistive circuit with a load connected where a portion of the voltage is tapped off, load resistances are calculated in the same manner as in other series-parallel circuits (Transparency #3)

(NOTE: A load can be in the form of a light bulb, motor, radio, or any other power dissipating device.)

EXAMPLE: To find total resistance, calculation must begin with R_4 and R_7 of the circuit in Figure 9, because they are in parallel

FIGURE 10



1. Calculate equivalent resistance of R_4 and R_7 ; use the formula $R_{e_1} = \frac{R}{N}$

EXAMPLE: Because these resistors are of equivalent value, the resistance-over-the-sum method may be used

$$R_{e_1} = \frac{R}{N}$$

$$= \frac{30\ \Omega}{2}$$

$$= 15\ \Omega$$

INFORMATION SHEET

2. Calculate equivalent resistance of R_{e_1} and R_3, which are in series; use the formula $R_{e_2} = R_{e_1} + R_3$

EXAMPLE: $R_{e_2} = R_{e_1} + R_3$

$= 15\ \Omega + 5\ \Omega$

$= 20\ \Omega$

3. Calculate equivalent resistance of R_{e_2} and R_6, which are in parallel; use the formula

$$R_{e_3} = \frac{R_{e_2} \times R_6}{R_{e_2} + R_6}$$

EXAMPLE: $R_{e_3} = \frac{R_{e_2} \times R_6}{R_{e_2} + R_6}$

$= \frac{20\ \Omega \times 30\ \Omega}{20\ \Omega + 30\ \Omega}$

$= \frac{600\ \Omega}{50\ \Omega}$

$= 12\ \Omega$

4. Calculate equivalent resistance of R_{e_3} and R_2, which are in series; use the formula $R_{e_4} = R_{e_3} + R_2$

EXAMPLE: $R_{e_4} = R_{e_3} + R_2$

$= 12\ \Omega + 8\ \Omega$

$= 20\ \Omega$

5. Calculate equivalent resistance of R_{e_4} and R_5, which are in parallel; use the formula

$$R_{e_5} = \frac{R}{N}$$

EXAMPLE: $R_{e_5} = \frac{R}{N}$

$= \frac{20\ \Omega}{2}$

$= 10\ \Omega$

INFORMATION SHEET

6. Calculate equivalent resistance of R_{e_5} and R_1, which are in series; use the formula $R_t = R_{e_5} + R_1$

   EXAMPLE: $R_t = R_{e_5} + R_1$

   $= 10\,\Omega + 10\,\Omega$

   $= 20\,\Omega$

7. Calculate total current flow of the circuit in Figure 10; use the formula $I_t = \frac{E_a}{R_t}$

   EXAMPLE: Total resistance was determined to be 20 ohms and the voltage applied is 200 volts

   $I_t = \frac{E_a}{R_t}$

   $= \frac{200\text{ V}}{20\,\Omega}$

   $= 10\text{ A}$

8. Calculate the voltage drop of R_1; use the formula $E_{R_1} = I_{R_1} \times R_1$

   EXAMPLE: Because the total current (10 A) flows through series resistor R_1, and the value of R_1 is known

   $E_{R_1} = I_{R_1} \times R_1$

   $= 10\text{ A} \times 10\,\Omega$

   $= 100\text{ V}$

9. Calculate the current flow through R_5 ; use the formula $I_{R_5} = \frac{E_{R_5}}{R_5}$

   EXAMPLE: Because 100 volts are dropped across R_1, the remaining voltage is dropped across the parallel path of R_5 and $R_{2,3,4,6,7}$. Using this voltage drop across R_5, calculate the current flow of R_5

   $I_{R_5} = \frac{E_{R_5}}{R_5}$

   $= \frac{100\text{ V}}{20\,\Omega}$

   $= 5\text{ A}$

INFORMATION SHEET

10. Calculate the voltage drop through R_2; use the formula $E_{R_2} = I_{R_2} \times R_2$

    EXAMPLE: Because 5 amps of current flow through R_5, the other 5 amps of current flow through R_2

    $$E_{R_2} = I_{R_2} \times R_2$$

    $$= 5\text{ A} \times 8\ \Omega$$

    $$= 40\text{ V}$$

11. Calculate the current flow through R_6; use the formula $I_{R_6} = \frac{E_{R_6}}{R_6}$

    EXAMPLE: Because the voltage at point A was 100 volts, and 40 volts was dropped through R_2, 60 volts remains to be felt across the parallel branch of R_6 and $R_{3,4,7}$

    $$I_{R_6} = \frac{E_{R_6}}{R_6}$$

    $$= \frac{60\text{ V}}{30\ \Omega}$$

    $$= 2\text{ A}$$

12. Calculate the voltage drop through R_3; use the formula $E_{R_3} = I_{R_3} \times R_3$

    EXAMPLE: Because 2 amps of current flow through R_6, the remaining 3 amps of current will flow through $R_{3,4,7}$

    $$E_{R_3} = I_{R_3} \times R_3$$

    $$= 3\text{ A} \times 5\ \Omega$$

    $$= 15\text{ V}$$

    (NOTE: Because 15 volts of the 60 volts are dropped across R_3, the remaining 45 volts are dropped equally across R_4 and R_7.)

13. Calculate the voltages available at points A, B, and C or the voltage drops across the load resistors

    a. Point A to ground = 100 V

    b. Point B to ground = 60 V

    c. Point C to ground = 45 V

INFORMATION SHEET

VII. Circuit characteristics when components are open or shorted (Transparencies #4, #5, and #6)

A. Measuring voltages across each component simplifies testing

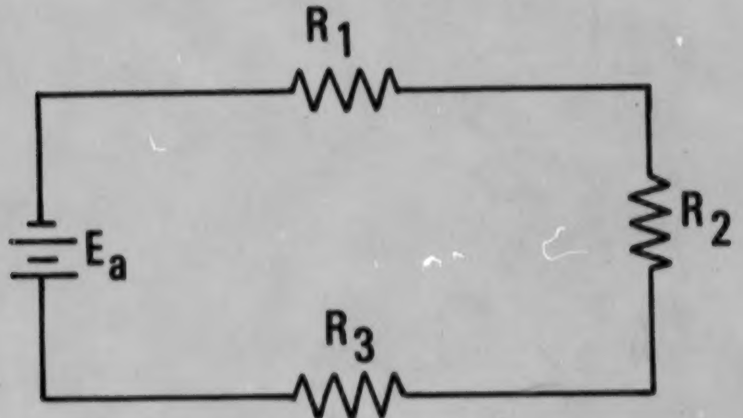
(NOTE: This method allows testing without disconnecting components.)

1. An open component will indicate maximum voltage due to the high internal resistance of the meter
2. Other components will measure zero volts
3. A shorted component will measure zero volts difference of potential
4. Other components will indicate a higher voltage than normal

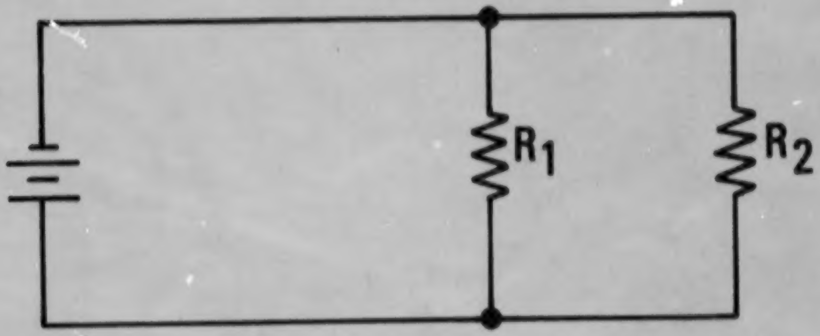
B. Making resistive measurements can be more difficult due to isolation of the components

1. An open resistor will measure infinity
2. A shorted resistor will indicate zero ohms

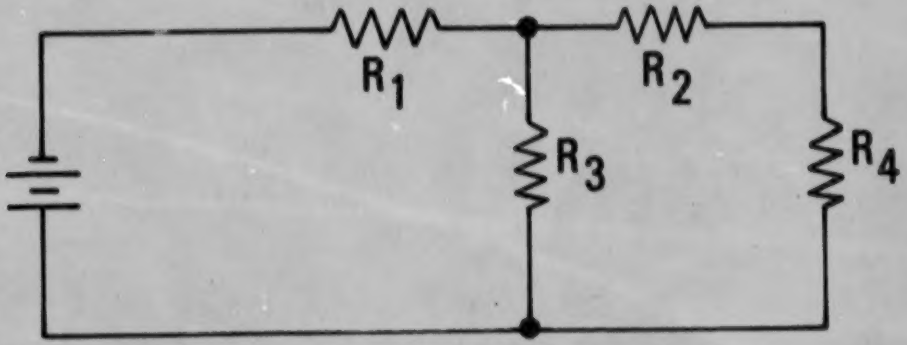
Resistive Circuits



Series Circuit

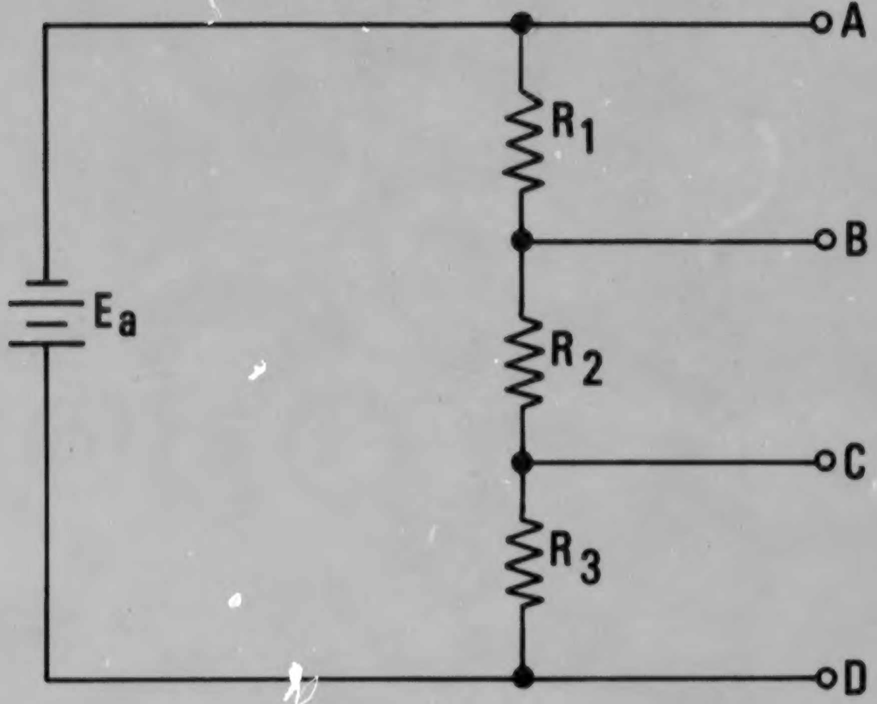


Parallel Circuit

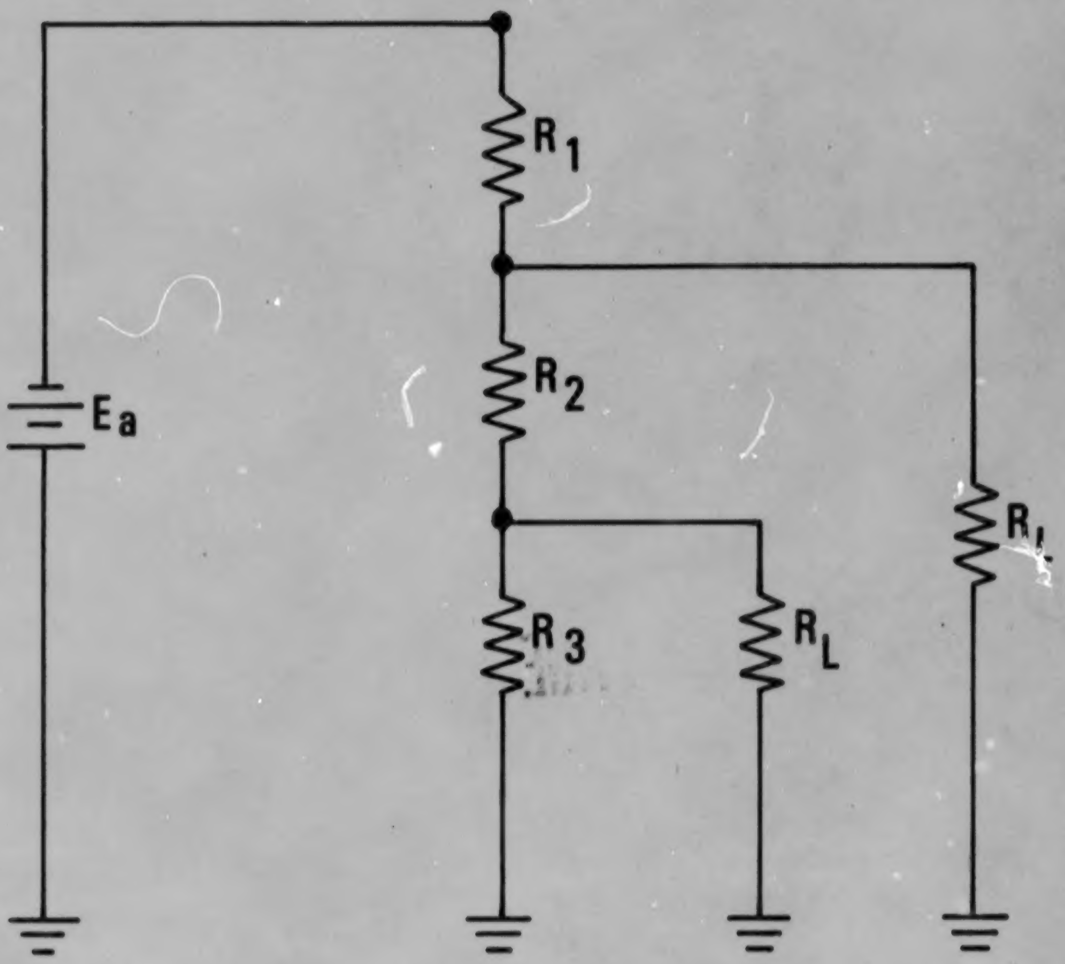


Series-Parallel Circuit

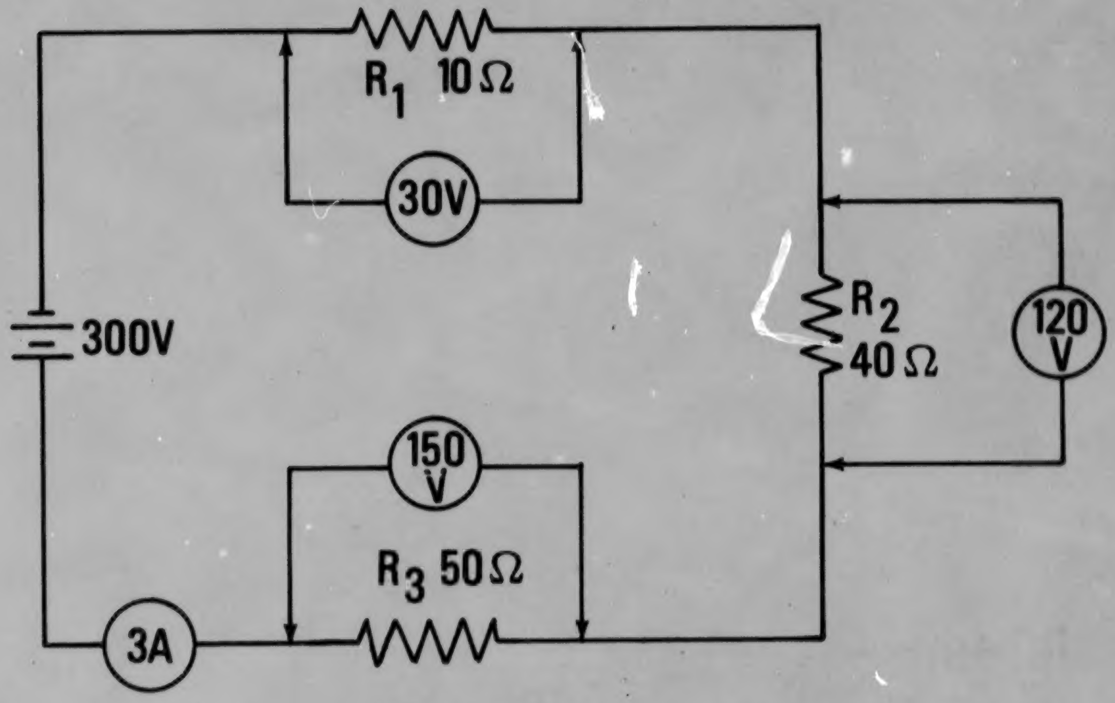
Unloaded Voltage Divider


A
R1
B
Ea
R2
C
R3
D

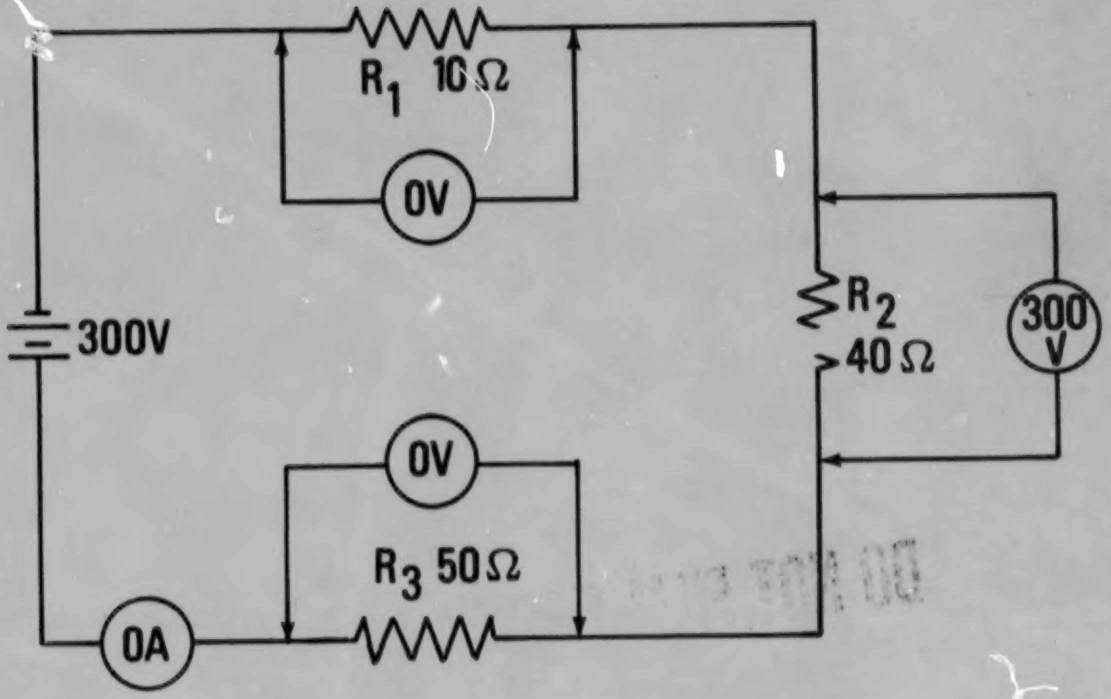
Loaded Voltage Divider


R1
R2
R3
RL
RL
Ea

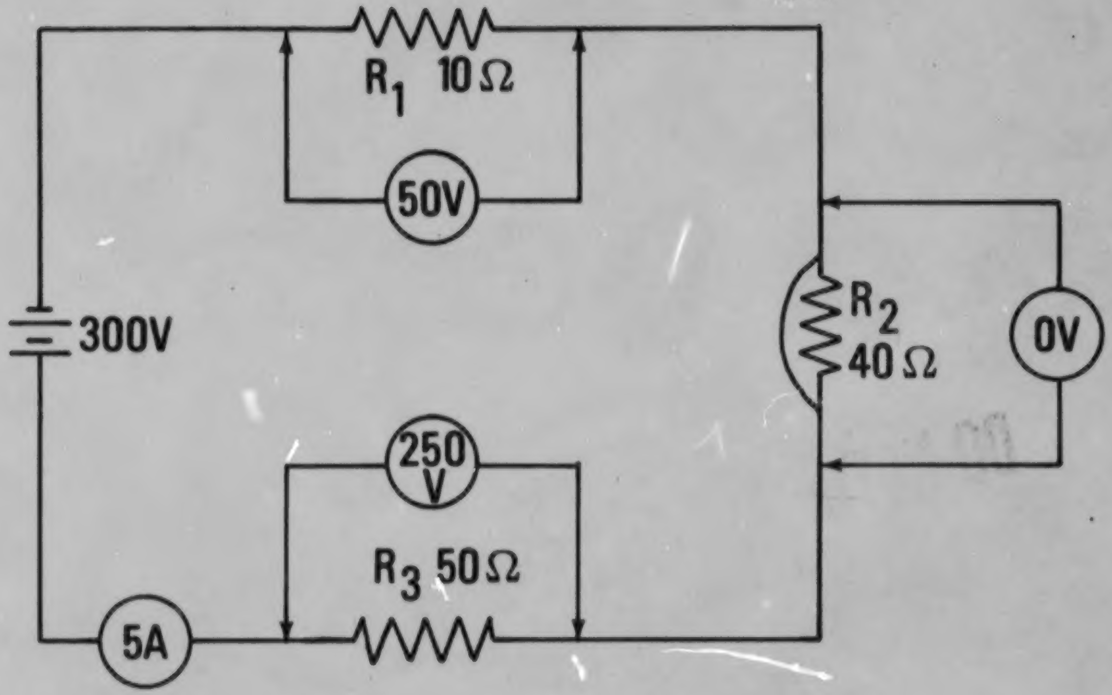
Series Circuit without Problems


R1 10 Ω
30V
300V
R2
40 Ω
120 V
150 V
R3 50 Ω
3A

Series Circuit with Open


R$_1$ 10 Ω
0V
300V
R$_2$ 40 Ω
300 V
0V
R$_3$ 50 Ω
0A

Series Circuit with Short


R$_1$ 10 Ω
50V
300V
R$_2$
40 Ω
0V
250 V
R$_3$ 50 Ω
5A

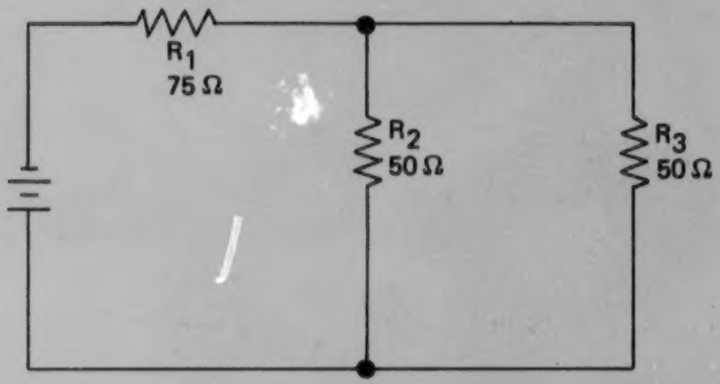
SERIES-PARALLEL CIRCUITS
UNIT II

ASSIGNMENT SHEET #1–CALCULATE THE EQUIVALENT RESISTANCE OF RESISTORS IN SERIES-PARALLEL

NAME ____________________ SCORE ____________

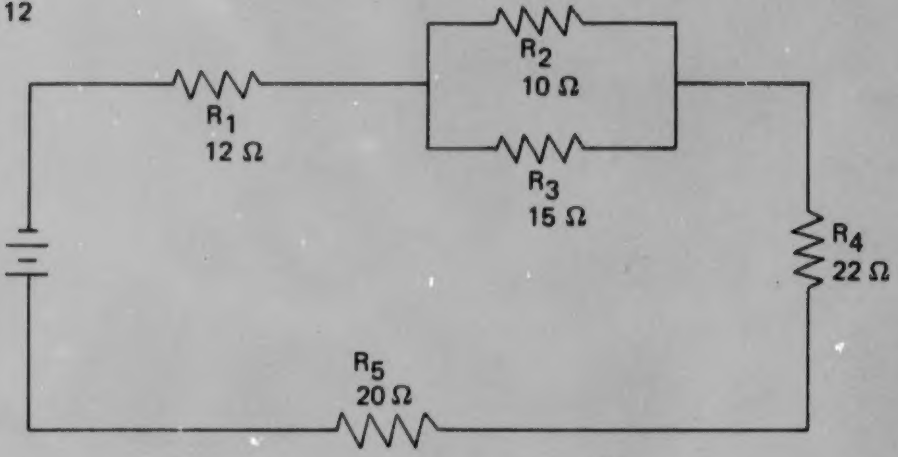
Find the equivalent resistance of the circuits shown in Figures 11-14. Have your instructor check your results. Record your answer in the blanks provided.

FIGURE 11


R_1
75 Ω
R_2
50 Ω
R_3
50 Ω

A. R_e = ____________________

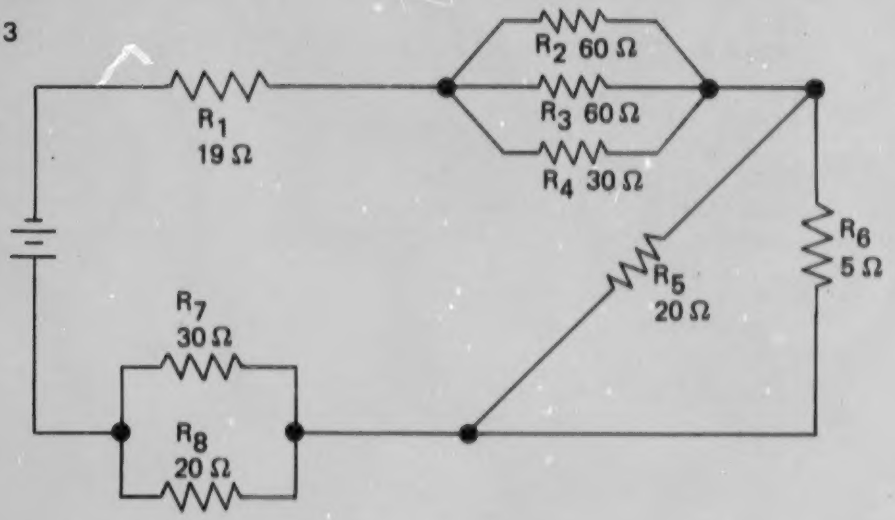
FIGURE 12


R_1
12 Ω
R_2
10 Ω
R_3
15 Ω
R_4
22 Ω
R_5
20 Ω

B. R_e = ____________________

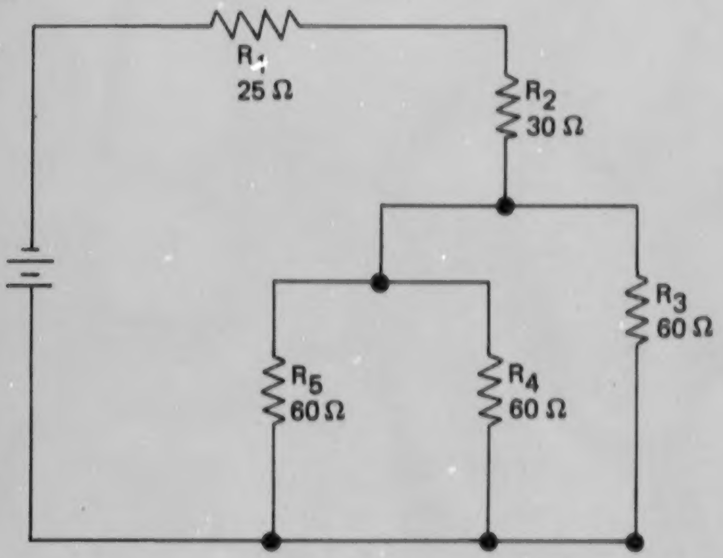
ASSIGNMENT SHEET #1

FIGURE 13


R1
19 Ω
R2 60 Ω
R3 60 Ω
R4 30 Ω
R5
20 Ω
R6
5 Ω
R7
30 Ω
R8
20 Ω

C. R_e = ____________________

FIGURE 14


R1
25 Ω
R2
30 Ω
R3
60 Ω
R4
60 Ω
R5
60 Ω

D. R_e = ____________________

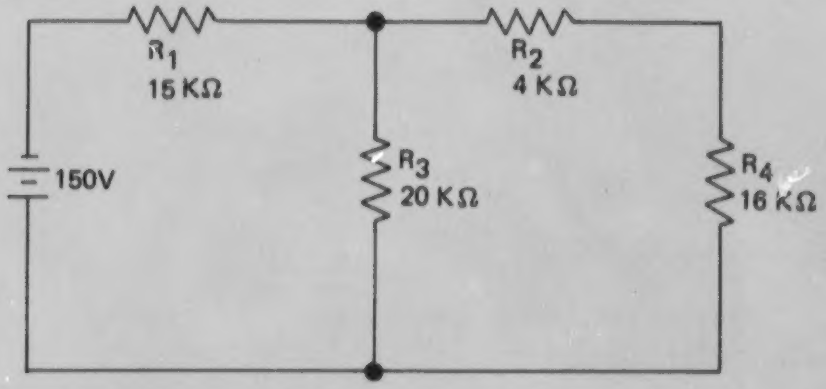
SERIES-PARALLEL CIRCUITS
UNIT II

ASSIGNMENT SHEET #2--CALCULATE CIRCUIT VALUES OF SERIES-PARALLEL COMPONENTS

NAME ______________________ SCORE ______________

Using the circuits in Figures 15 and 16, find the resistance, voltage, and current values shown below. Use the back of this page for scratch work, if needed. Have your instructor check your results.

FIGURE 15



A.

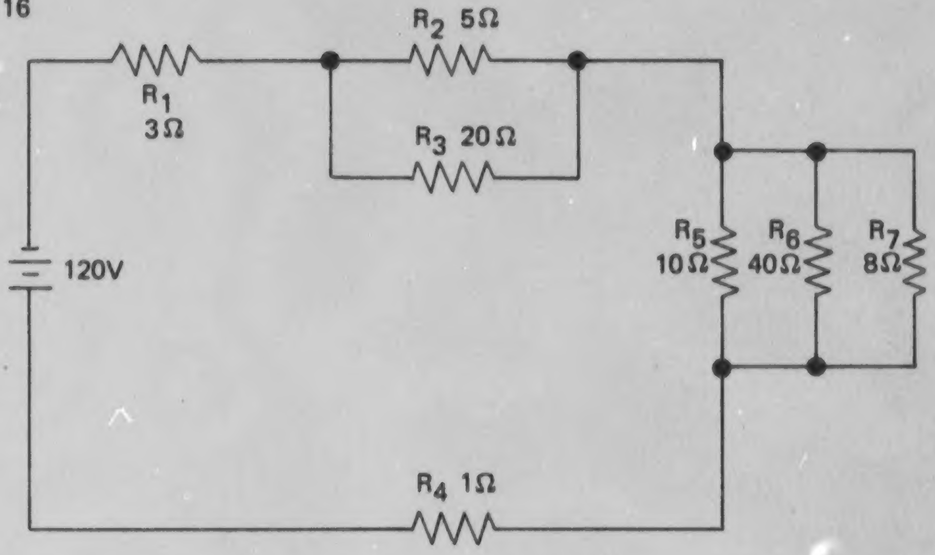
1. R_t = ______________
2. I_t = ______________
3. I_{R_1} = ______________
4. I_{R_3} = ______________
5. $I_{R_{2,4}}$ = ______________
6. Which components are in parallel? ______________
7. Which components are in series? ______________

____
8. E_{R_1} = ______________
9. E_{R_3} = ______________
10. $E_{R_{2,4}}$ = ______________
11. E_{R_2} = ______________
12. E_{R_4} = ______________

ASSIGNMENT SHEET #2

ASSIGNMENT SHEET #2

FIGURE 16


R2 5Ω
R1
3Ω
R3 20Ω
120V
R5
10Ω
R6
40Ω
R7
8Ω
R4 1Ω

B.

1. R_t = ______________________
2. I_t = ______________________
3. I_{R_2} = ______________________
4. I_{R_3} = ______________________
5. I_{R_4} = ______________________
6. I_{R_5} = ______________________
7. I_{R_6} = ______________________
8. I_{R_7} = ______________________
9. E_{R_1} = ______________________
10. E_{R_2} = ______________________
11. E_{R_6} = ______________________
12. E_{R_4} = ______________________

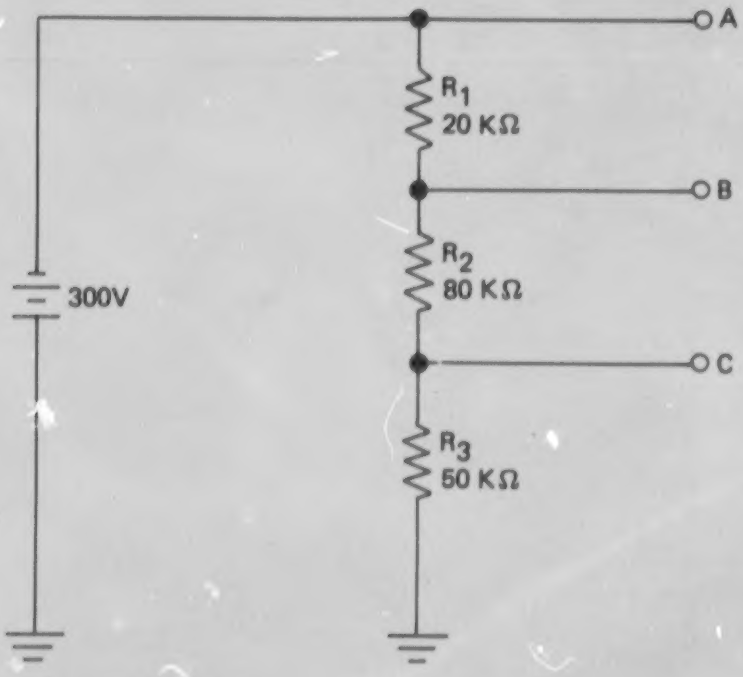
SERIES-PARALLEL CIRCUITS
UNIT II

ASSIGNMENT SHEET #3--CALCULATE VOLTAGES AVAILABLE IN UNLOADED AND LOADED VOLTAGE DIVIDERS

NAME ______________________ SCORE ____________

Calculate the voltages available from the voltage dividers in Figures 17-18. Use the back of this page for scratch work, if needed. Have your instructor check your answers.

FIGURE 17



A. 1. Voltage at Point A with respect to Gnd = ______________

2. Voltage at Point B with respect to Gnd = ______________

3. Voltage at Point C with respect to Gnd = ______________

4. Voltage at Point C with respect to Point A = ______________

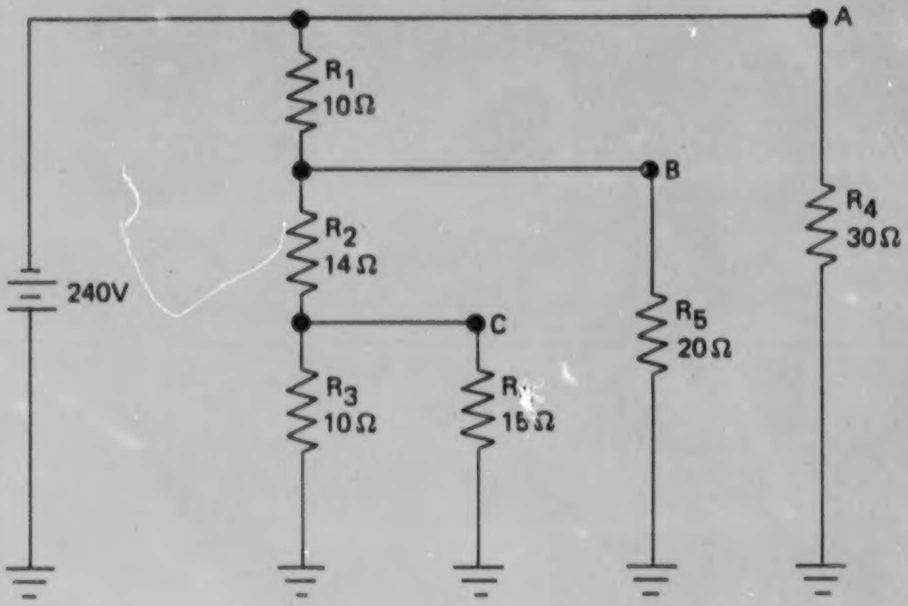
5. Voltage at Point B with respect to Point C = ______________

6. Voltage at Point B with respect to Point A = ______________

ASSIGNMENT SHEET #3

ASSIGNMENT SHEET #3

FIGURE 18


A
R1
10Ω
B
R4
30Ω
R2
14Ω
240V
C
R5
20Ω
R3
10Ω
R
15Ω

B. 1. Voltage at Point A with respect to Gnd = ____________________

2. Voltage at Point B with respect to Gnd = ____________________

3. Voltage at Point C with respect to Gnd = ____________________

SERIES-PARALLEL CIRCUITS
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 100 Ω

B. 60 Ω

C. 50 Ω

D. 75 Ω

Assignment Sheet #2

A.
1. 25 K
2. 6 mA
3. 6 mA
4. 3 mA
5. 3 mA
6. R_2 and R_4 with R_3
7. R_2 and R_4; R_1 with R_2, R_3, and R_4
8. 90 V
9. 60 V
10. 60 V
11. 12 V
12. 48 V

B.
1. 12 Ω
2. 10 A
3. 8 A
4. 2 A
5. 10 A
6. 4 A
7. 1 A
8. 5 A
9. 30 V
10. 40 V
11. 40 V
12. 10 V

Assignment Sheet #3

A.
1. 300 V
2. 260 V
3. 100 V
4. -200 V
5. 160 V
6. -40 V

B.
1. 240 V
2. 120 V
3. 36 V

SERIES-PARALLEL CIRCUITS
UNIT II

JOB SHEET #1--MEASURE RESISTANCE IN A SERIES-PARALLEL CIRCUIT

I. Equipment and materials

   A. Multimeter

   B. Circuit board

   C. Resistors--2, 10 Kohms

   D. Resistor--20 Kohms

   E. Resistor--15 Kohms

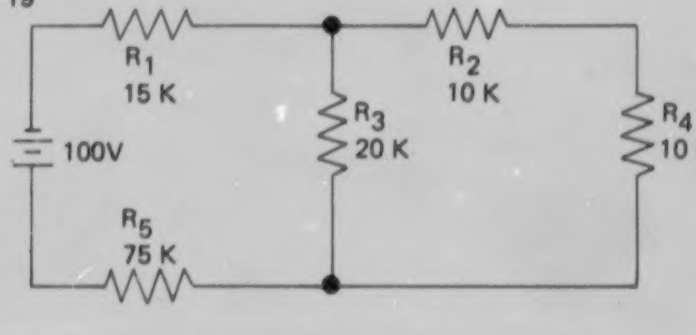
   F. Resistor--75 Kohms

   G. DC power supply--Capable of 120 VDC

II. Procedure

   A. Connect circuit as shown in Figure 19

FIGURE 19



(NOTE: Have instructor check the circuit.)

   B. Calculate the equivalent resistance of the R_2, R_4 branch

   R_e = ______________________________

   C. Calculate the equivalent resistance of the R_2, R_3, R_4 parallel branch

   R_e = ______________________________

   D. Calculate the total resistance of the circuit

   R_t = ______________________________

JOB SHEET #1

E. Prepare the multimeter to measure resistance

(CAUTION: Be sure power to circuit is turned off before connecting or disconnecting multimeter.)

F. Measure the resistance of the R_2, R_4 parallel branch

R = ______________________________

G. Measure the resistance of the R_2, R_3, R_4 parallel branch

R = ______________________________

H. Measure the total resistance of the series-parallel circuit in Figure 19

R_t = ______________________________

I. Do the measured readings compare with the calculated readings? __________

(NOTE: Before disconnecting circuit, check with the instructor.)

J. Put equipment and materials away

SERIES-PARALLEL CIRCUITS
UNIT II

JOB SHEET #2--MEASURE CURRENT IN A SERIES-PARALLEL CIRCUIT

I. Equipment and materials

A. Multimeter

B. Circuit board

C. Resistors--2, 10 Kohms

D. Resistor--20 Kohms

E. Resistor--15 Kohms

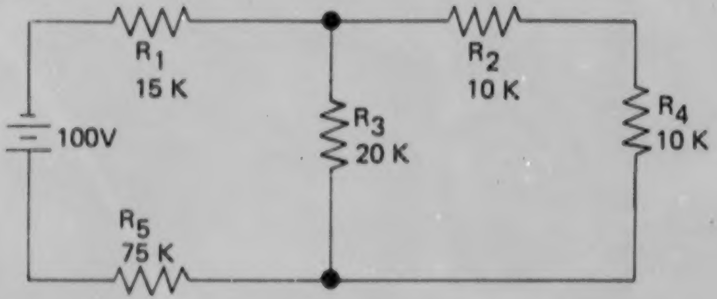
F. Resistor--75 Kohms

G. DC power supply--Capable of 120 VDC

II. Procedure

A. Connect circuit as shown in Figure 20

FIGURE 20



(NOTE: Have instructor check the circuit.)

B. Calculate the current of the R_2, R_4 parallel branch

I = ______________________________

C. Calculate the current of the R_3 parallel branch

I = ______________________________

D. Calculate the total current of the circuit

I_t = ______________________________

JOB SHEET #2

E. Prepare the multimeter to measure current

(CAUTION: Be sure power to circuit is turned off before connecting or disconnecting multimeter.)

F. Measure the current of the R_2, R_4 parallel branch

I = ________________________________

G. Measure the current of the R_3 parallel branch

I = ________________________________

H. Measure the total current in the circuit in Figure 20

I_t = ________________________________

I. Do the measured readings compare with the calculated readings? __________

(NOTE: Before disconnecting the circuit, check with the instructor.)

J. Put equipment and materials away

SERIES-PARALLEL CIRCUITS
UNIT II

JOB SHEET #3--MEASURE VOLTAGE IN A SERIES-PARALLEL CIRCUIT

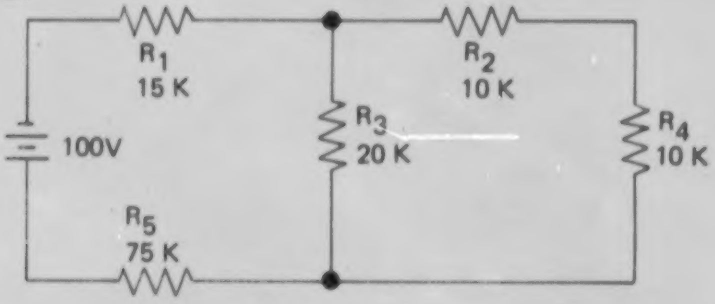
I. Equipment and materials

- A. Multimeter
- B. Circuit board
- C. Resistors--2, 10 Kohm
- D. Resistor--20 Kohm
- E. Resistor--15 Kohm
- F. Resistor--75 Kohm
- G. DC power supply

II. Procedure

A. Connect circuit as shown in Figure 21

FIGURE 21



(NOTE: Have instructor check the circuit.)

B. Calculate the voltage drop across each resistor

R_1 = ______________________

R_2 = ______________________

R_3 = ______________________

R_4 = ______________________

R_5 = ______________________

JOB SHEET #3

C. Prepare the multimeter to measure voltage

D. Measure the voltage drop across each resistor shown in Figure 21

R_1 = ______________________________

R_2 = ______________________________

R_3 = ______________________________

R_4 = ______________________________

R_5 = ______________________________

E. Do the measured voltage readings compare with the calculated readings?

____

(NOTE: Before disconnecting circuit, check with the instructor.)

F. Put equipment and materials away

SERIES-PARALLEL CIRCUITS
UNIT II

JOB SHEET #4--ANALYZE LOADED AND UNLOADED VOLTAGE DIVIDERS

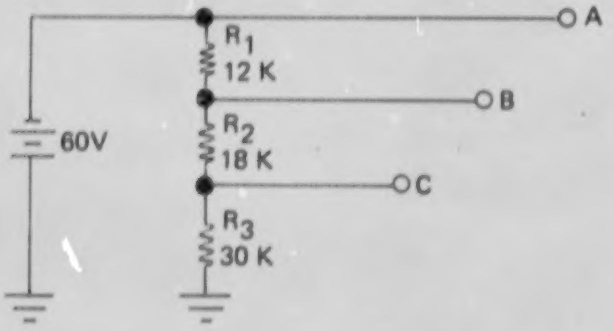
I. Equipment and materials

- A. Multimeter
- B. Circuit board
- C. Resistor--30 Kohms
- D. Resistor--20 Kohms
- E. Resistor--18 Kohms
- F. Resistor--45 Kohms
- G. Resistor--12 Kohms
- H. DC power supply--Capable of 120 VDC

II. Procedure

A. Connect the unloaded voltage divider circuit shown in Figure 22

FIGURE 22



(NOTE: Have instructor check the circuit.)

B. Calculate the total resistance of the circuit

R_t = ______________________________

C. Calculate the total current of the circuit

I_t = ______________________________

JOB SHEET #4

D. Calculate the voltages at the following points

Point A with respect to Gnd = ____________________

Point B with respect to Gnd = ____________________

Point C with respect to Gnd = ____________________

Point C with respect to point A = ____________________

Point B with respect to point A = ____________________

Point B with respect to point C = ____________________

Gnd with respect to point C = ____________________

E. Measure the total resistance of the circuit

R_t = ____________________

F. Measure the total current of the circuit

I_t = ____________________

G. Measure the voltage at the following points

Point A with respect to Gnd = ____________________

Point B with respect to Gnd = ____________________

Point C with respect to Gnd = ____________________

Point C with respect to point A = ____________________

Point B with respect to point A = ____________________

Point B with respect to point C = ____________________

Gnd with respect to point C = ____________________

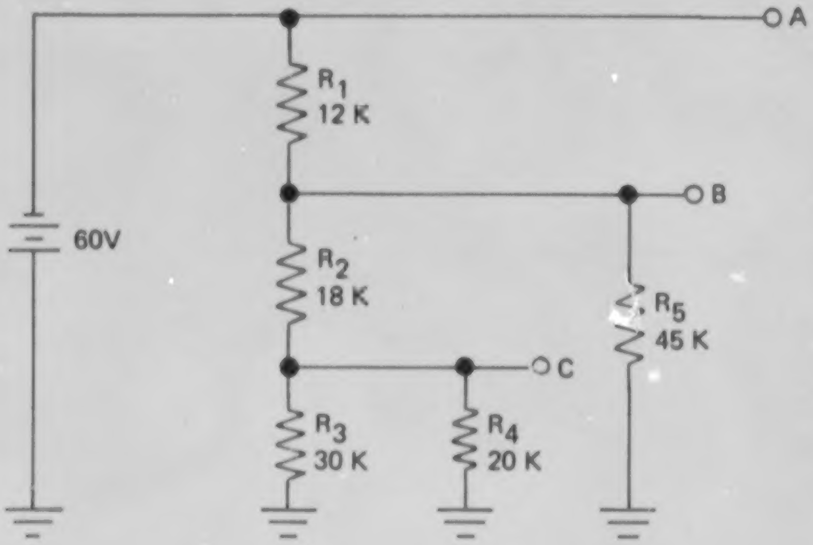
H. Do the measured values all agree with the calculated values? __________

(NOTE: If the measured values do not agree with the calculated values, check with the instructor.)

JOB SHEET #4

I. Connect two additional resistors in the circuit shown in Figure 22 as shown below in Figure 23

FIGURE 23



(NOTE: Have instructor check the circuit.)

J. What type circuit is shown in Figure 23? ______________________________

K. Should the total resistance increase, decrease, or remain the same? ________
____

L. Should the total current increase, decrease, or remain the same? __________
____

M. Calculate the total resistance in the circuit

R_t = ____

N. Calculate the total current in the circuit

I_t = ____

O. Measure the total resistance in the circuit

R_t = ____

P. Measure the total current in the circuit

I_t = ____

JOB SHEET #4

Q. Measure the voltage at the following points of the loaded voltage divider

Point A with respect to Gnd = ____________

Point B with respect to Gnd = ____________

Point C with respect to Gnd = ____________

Point C with respect to point A = ____________

Point B with respect to point A = ____________

Point B with respect to point C = ____________

Gnd with respect to point C = ____________

R. Did the voltage readings vary between the unloaded voltage divider and the loaded voltage divider? ____________

S. If so, why? ____________

(NOTE: Check with the instructor before disconnecting the circuit.)

T. Put equipment and materials away

SERIES-PARALLEL CIRCUITS
UNIT II

JOB SHEET #5--TROUBLESHOOT SERIES-PARALLEL CIRCUITS

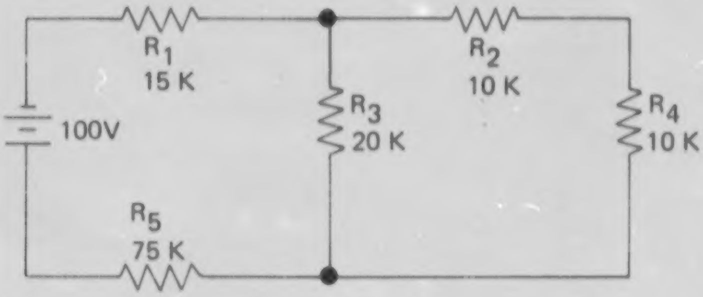
I. Equipment and materials

- A. Multimeter
- B. Circuit board
- C. Resistors--2, 10 Kohms
- D. Resistor--20 Kohms
- E. Resistor--15 Kohms
- F. Resistor--75 Kohms
- G. DC power supply--Capable of 120 VDC

II. Procedure

- A. Connect the series-parallel circuit as shown in Figure 24

FIGURE 24



(NOTE: Have instructor check the circuit.)

- B. Look back over Job Sheets #1, #2, and #3 to familiarize yourself with the voltages, current, and resistance values of the circuit in Figure 24
- C. Ask the instructor to insert a "trouble" in the Figure 24 circuit
- D. Troubleshoot the circuit using correct troubleshooting procedures

JOB SHEET #5

E. Indicate the problem and explain the procedures used to locate the trouble

(NOTE: At this point, the instructor should check student work and discuss troubleshooting procedures used.)

F. Repeat steps C through E for each additional trouble the instructor adds

G. Indicate the problems and explain procedures used to locate them

H. Put equipment and materials away

SERIES-PARALLEL CIRCUITS
UNIT II

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with series-parallel circuits to their correct definitions. Write the correct numbers in the blanks.

_____a. Common point in a circuit

_____b. Difference of voltage between one end of an electronic component and the other end

_____c. Components connecting end-to-end in a circuit to provide a single path for current flow

_____d. Abnormal, relatively low resistance connection between two points of a circuit

_____e. Resistance connected across a voltage source where only a portion of the voltage is tapped off

_____f. Connecting components both end-to-end and to the same terminals, combining both the series circuit and the parallel circuit

_____g. Circuit interruption that results in an incomplete path for current flow

_____h. Very sensitive meter for measuring small values of current, both in the positive and negative direction

_____i. Determinant, such as voltage, frequency, and component values, that determines other characteristics of the circuit

_____j. Components connecting to the same pair of terminals so that current must take more than one path

_____k. Resistance connected to a voltage source which consumes power

_____l. Instrument used to measure unknown resistance values

1. Series
2. Parallel
3. Series-parallel
4. Open
5. Voltage divider
6. Load
7. Reference point
8. Parameter
9. Potential difference
10. Galvanometer
11. Wheatstone bridge
12. Short

TEST

2. Match abbreviations and symbols associated with series-parallel to their correct definitions. Write the correct numbers in the blanks.

______a. Battery symbol

______b. Resistor symbol

______c. Total current

______d. Equivalent resistance

______e. Resistor voltage

______f. Resistor; resistance

______g. Ground

______h. Kilo

______i. Ohm

______j. Alternating current

______k. Voltage; volt

______l. Ground symbol

______m. Voltage applied

______n. Total resistance

______o. Resistor current

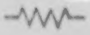
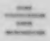
______p. Current

______q. Kilohm

______r. Number (of components)

______s. Direct current

______t. Amperage; amp

1. A
2. V
3. AC
4. DC
5. N
6. Gnd
7. K
8. R
9. I
10. Kohm
11. E_R
12. I_R
13. R_t
14. R_e
15. I_t
16. E_a
17. Ω
18. 
19.
20. 

3. Distinguish between the characteristics of series circuits and parallel circuits. Write an "S" for the characteristics of a series circuit and a "P" for the characteristics of parallel circuits.

______a. Components are connected side-by-side in the same pair of terminals

______b. Current is equal throughout the circuit

______c. Voltage is equal through parallel branches

______d. All components are connected end-to-end

TEST

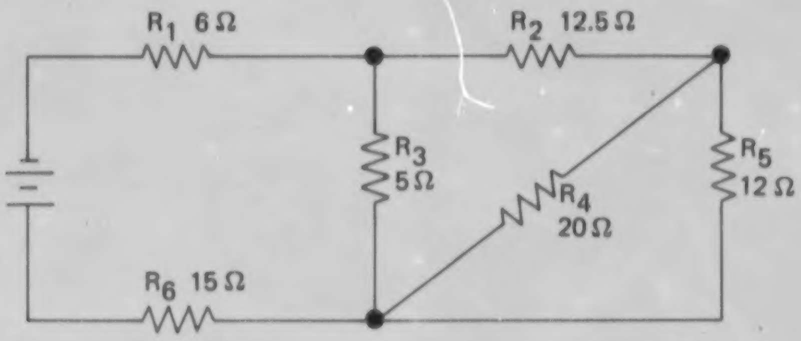
______e. Total resistance is equal to the sum of all resistances

______f. Total resistance may be calculated using one of the resistance formulas for parallel circuits

______g. The sum of the individual voltage drops is equal to the voltage applied

______h. Current divides into each branch dependent upon the resistance

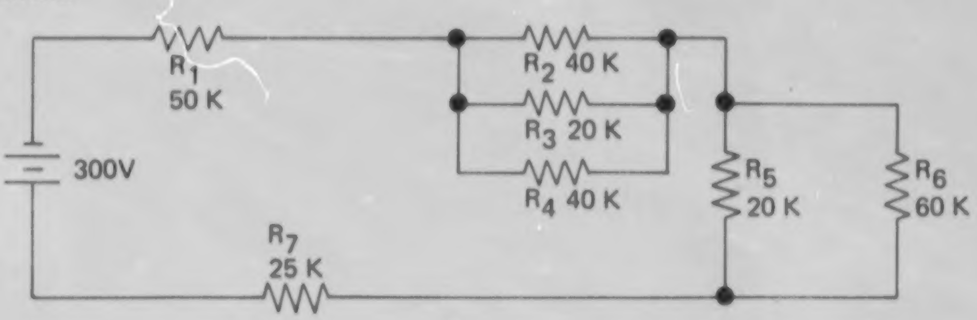
4. Calculate total resistance in the following series-parallel circuit.



R_1 6 Ω
R_2 12.5 Ω
R_3 5 Ω
R_4 20 Ω
R_5 12 Ω
R_6 15 Ω

R_t = ______________________________

5. Calculate current and voltage using Ohm's Law and Kirchoff's laws of voltage and current.



R_1 50 K
300V
R_2 40 K
R_3 20 K
R_4 40 K
R_5 20 K
R_6 60 K
R_7 25 K

a. R_t = ______________________

b. I_t = ______________________

c. I_{R_1} = ______________________

d. I_{R_2} = ______________________

e. I_{R_3} = ______________________

f. I_{R_4} = ______________________

g. I_{R_5} = ______________________

h. I_{R_6} = ______________________

i. E_{R_1} = ______________________

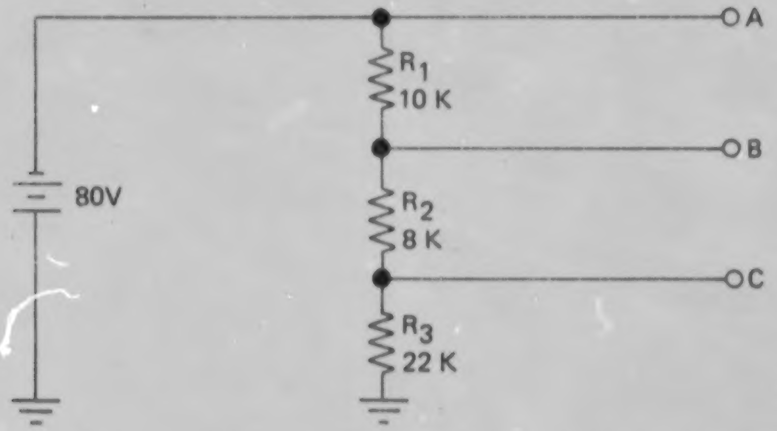
j. E_{R_4} = ______________________

k. E_{R_5} = ______________________

l. E_{R_7} = ______________________

TEST

6. Calculate voltages available in unloaded and loaded voltage dividers.


A
R1
10 K
B
80V
R2
8 K
C
R3
22 K

a. 1) ______________ Voltage at Point A with respect to Gnd

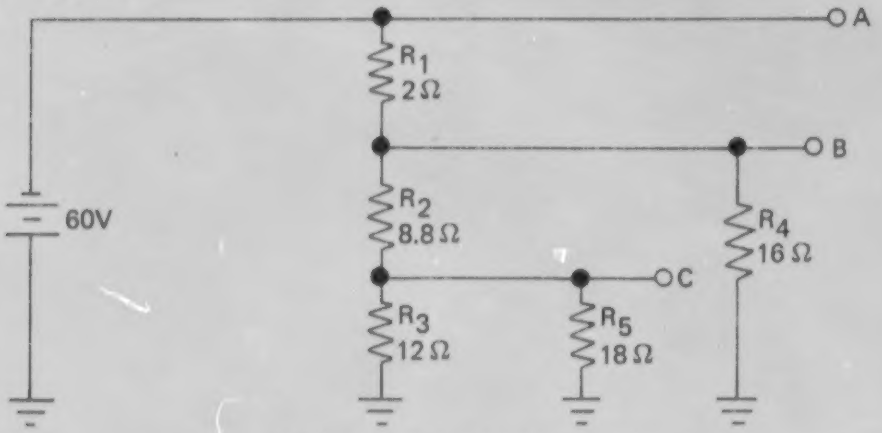
2) ______________ Voltage at Point B with respect to Gnd

3) ______________ Voltage at Point C with respect to Gnd

4) ______________ Voltage at Point C with respect to Point A

5) ______________ Voltage at Point B with respect to Point C

6) ______________ Voltage at Point B with respect to Point A


A
R1
2 Ω
B
60V
R2
8.8 Ω
R4
16 Ω
C
R3
12 Ω
R5
18 Ω

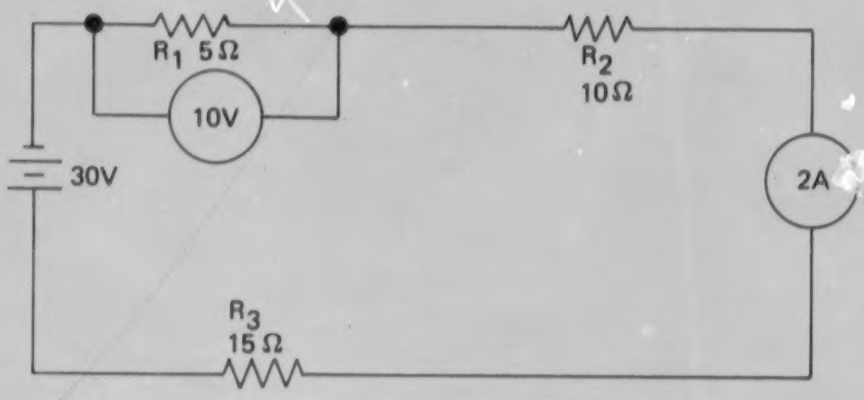
b. 1) ______________ Voltage at Point A with respect to Gnd

2) ______________ Voltage at Point B with respect to Gnd

3) ______________ Voltage at Point C with respect to Gnd

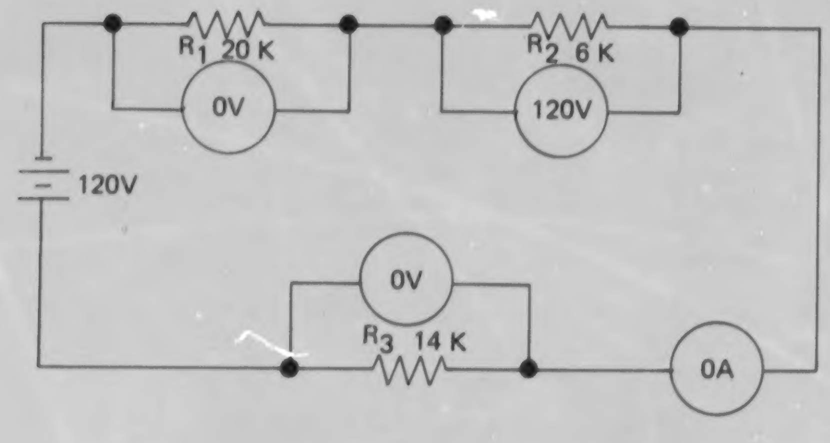
TEST

7. Determine circuit characteristics when components are open or shorted. Specify which components are open and which are shorted. Write your answers in the blanks below each circuit.



R1 5Ω
10V
R2
10Ω
30V
2A
R3
15 Ω

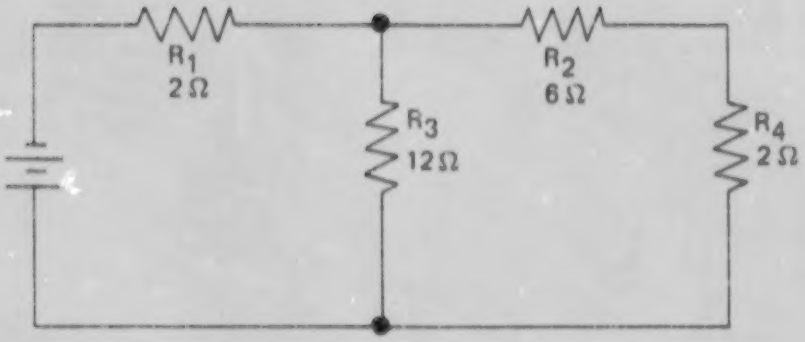
a. ______________________________



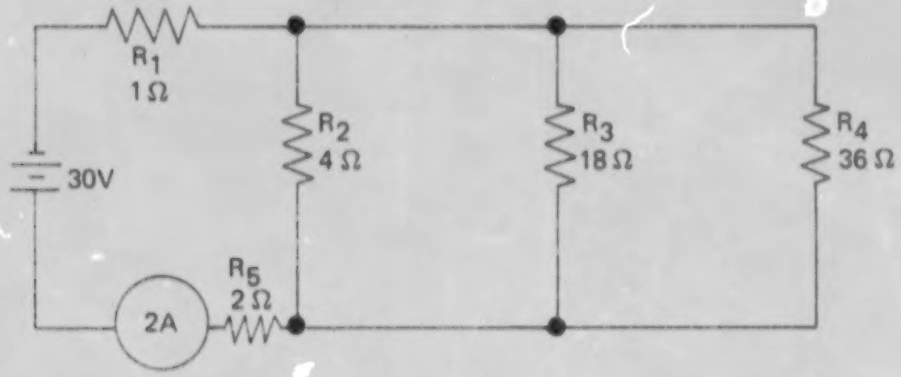
R1 20 K
0V
R2 6 K
120V
120V
0V
R3 14 K
0A

b. ______________________________

TEST



c. ______________________________



d. ______________________________

(NOTE: Test questions 8-10 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

8. Calculate the equivalent resistance of resistors in series-parallel.

9. Calculate circuit values of series-parallel components.

10. Demonstrate the ability to

    a. Measure resistance in a series-parallel circuit.

    b. Measure current in a series-parallel circuit.

    c. Measure voltage in a series-parallel circuit.

    d. Analyze loaded and unloaded voltage dividers.

    e. Troubleshoot series-parallel circuits.

SERIES-PARALLEL CIRCUITS
UNIT II

ANSWERS TO TEST

1. a. 7
   b. 9
   c. 1
   d. 12
   e. 5
   f. 3
   g. 4
   h. 10
   i. 8
   j. 2
   k. 6
   l. 11

2. a. 20
   b. 18
   c. 15
   d. 14
   e. 11
   f. 8
   g. 6
   h. 7
   i. 17
   j. 3
   k. 2
   l. 19
   m. 16
   n. 13
   o. 12
   p. 9
   q. 10
   r. 5
   s. 4
   t. 1

3. a. P
   b. S
   c. P
   d. S
   e. S
   f. P
   g. S
   h. P

4. 25 Ω

ANSWERS TO TEST

5. a. 100 K
   b. 3 mA
   c. 3 mA
   d. .75 mA
   e. 1.5 mA
   f. .75 mA
   g. 2.25 mA
   h. .75 mA
   i. 150 V
   j. 30 V
   k. 45 V
   l. 75 V

6. a. 1. 80 V
      2. 60 V
      3. 44 V
      4. -36 V
      5. 16 V
      6. -20 V
   b. 1. 60 V
      2. 48 V
      3. 21.6 V

7. a. R_3 shorted
   b. R_2 open
   c. R_3 open
   d. R_2 open

8. Evaluated to satisfaction of instructor

9. Evaluated to satisfaction of instructor

10. Performance skills evaluated to satisfaction of instructor

POWER
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to calculate power of various circuits, determine maximum power transfer, and measure power in electrical circuits. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with DC power to their correct definitions.
2. Match abbreviations associated with electrical power to their correct definitions.
3. Write the formulas for electrical power in terms of amperage, voltage, and resistance.
4. Calculate electrical power from measurements of amperage, voltage, and resistance.
5. Calculate electrical energy used in direct current circuits.
6. Match power ratings to their correct descriptions.
7. Calculate effects of conductor resistance.
8. Name reasons for using high voltage to supply electrical power to distant loads.
9. State how maximum power transfer is accomplished.
10. Name the characteristics of a wattmeter.
11. Calculate power loss in transmission lines.
12. Calculate heat developed in equipment.
13. Calculate voltage drop and power loss in an extension cable.
14. Demonstrate the ability to
    a. Measure power to a lamp.
    b. Determine the maximum power transfer point on a resistor circuit.

POWER
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Demonstrate the effects of excess power on electrical components.

   H. Give test.

II. Instructional materials

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM #1--Remembering Power Formulas

      2. TM #2--Fundamental Formulas

      3. TM #3--Impedance Matching to Attain Maximum Power Transfer

      4. TM #4--Wattmeter Diagram

   D. Assignment sheets

      1. Assignment Sheet #1--Calculate Power Loss in Transmission Lines

      2. Assignment Sheet #2--Calculate Heat Developed in Equipment

      3. Assignment Sheet #3--Calculate Voltage Drop and Power Loss in an Extension Cable

   E. Answers to assignment sheets

SUGGESTED ACTIVITIES

F. Job sheets

1. Job Sheet #1--Measure Power to a Lamp
2. Job Sheet #2--Determine the Maximum Power Transfer Point on a Resistor Circuit

G. Test

H. Answers to test

III. Unit references

A. *Electrical Fundamentals.* TM 11-661, Department of the Army Technical Manual. Washington: U.S. Government Printing Office, 1951.

B. Loper, Orla E. *Direct Current Fundamentals.* Albany, New York: Delmar Publishers, 1959.

C. *National Electrical Code 1978.* NFPA No. 70-1978. Boston: National Fire Prevention Association, 1977.

D. Seippel, Robert G. *Direct Current Circuit Analysis.* Chicago: American Technical Society, 1975.

POWER
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Electrical power--Rate of doing work; expressed in units of watts or joules per second

B. Milliwatt--One one-thousandth of a watt

C. Kilowatt--One thousand watts

D. Megawatt--One million watts

E. Electrical energy--Amount of work; product of power and time, usually expressed in kilowatt-hours

F. Dissipate heat--Give off heat by radiation, conduction, and convection

G. Load--Equipment or devices being supplied power

H. Line loss--Power wasted in electrical wires due to heating caused by electrical current flow; heat loss of lines

I. Kilovolt--One thousand volts

J. Voltage drop--Voltage reduction, usually due to resistance

K. Internal resistance--Resistance that is part of the internal electrical, chemical, and mechanical workings of an electrical device; considered a single resistor

L. Impedance--Total opposition of a device or circuit to current flow; accounts for all alternating current and direct current effects

M. Maximum power transfer point--Point where internal resistance of the load is equal to the resistance of the source or supplier of power; point of matched impedance

N. Real power--Component of apparent power that represents true work; expressed in watts, it is equal to volt-amperes multiplied by the power factor

II. Abbreviations associated with electrical power

A. mW--Milliwatt

B. kW--Kilowatt

C. MW--Megawatt

D. kW-hr--Kilowatt-hour

E. kV--Kilovolt

F. E--Voltage; energy

INFORMATION SHEET

G. **DC**--Direct current

H. **AC**--Alternating current

I. **W**--Watt

J. **V**--Volt

K. **A**--Ampere

L. **VDC**--Volts direct current

M. **VAC**--Volts alternating current

N. **J**--Joule

O. **Ω**--Ohm

P. **AWG**--American wire gauge

Q. **R_m**--Meter resistance

III. Electrical power formulas (Transparency #1)

A. Voltage and amperage--$P = IE$

B. Resistance and amperage--$P = I^2 R$

(NOTE: $I^2 R$ is an equivalent expression for $I \times I \times R$.)

IV. Calculating electrical power (Transparency #2)

A. Amperage and voltage measurements--Use the formula, $P = IE$

EXAMPLE: An electric lamp made to operate at 12 volts DC has a current draw of 5 amperes. What is the lamp's power rating?

Solution: $P = IE$

$= 5\ A \times 12\ V$

$= 60\ W$ (Lamp's power rating)

B. Ampere and resistance measurements--Use the formula, $P = I^2 R$

EXAMPLE: A 1200 foot (366 meter) line of electrical wire connects an alarm buzzer to a temperature sensor 600 feet away. If the buzzer operates at 2 amperes and the wire has a resistance of 6.39 ohms per 1000 feet, what will be the rate of energy loss in the conductor?

INFORMATION SHEET

Solution: The 1200 foot wire has 1.2 x 6.39 ohms of total resistance or 7.67 ohms

$P = I^2 R$

$= 2 \times 2 \times 7.67$

$= 30.68$ W (Energy loss in the conductor)

V. Calculating electrical energy used in direct current circuits--Multiply power times the time applied (E = P x Time), usually expressed as kilowatt-hours (kW-hr)

EXAMPLE: Eight electric lamps are operated each night to light a billboard. The lamps are each 150 watts, and they operate an average of 11 1/2 hours per night. What is the energy used, on the average, each night?

(NOTE: First find the total power then multiply times the hours.)

Solution: Total power = 8 Lamps x 150 W

= 1,200 W

E = P x Time

= 1,200 W x 11.5 hrs

= 13,800 W-hrs

= 13.8 kW-hrs

EXAMPLE: An emergency generator is powered by a diesel engine. The diesel engine uses three 24-volt batteries in parallel for starting power. If each of the three batteries delivers 250 amperes for 15 minutes before the engine starts, how much electrical energy is required?

Solution: P = IE

= 3 Batteries x 250 A x 24 V

= 18,000 W

E = P x Time

= 18,000 W x 15 min

= 18,000 W x .25 hr

= 4500 W-hrs

= 4.5 kW-hrs

INFORMATION SHEET

VI. Power ratings

A. Power requirement--Power at which a device is intended to operate; probably will not operate properly at a lower power; may become damaged at a higher power operation

EXAMPLES: 100 watt light bulb, 40 watt soldering iron, 35 kilowatt electric heating unit

B. Heat dissipation--Maximum power a device can dissipate without possible damage; usually much higher than the intended operating power; damage is certain at higher power operations

EXAMPLES: 2 watt resistor, 1/4 watt transistor, 500 milliwatt (1/2 watt) diode

C. Power output--Maximum power which a device can deliver to a load; power output in form of heat, sound, and mechanical energy; may operate at or anywhere below the output rating

EXAMPLES: 30 kilowatt direct current generator, 70 ampere-hour automobile battery with nominal 12 volts understood

(NOTE: Usually power output specifications are applied to AC equipment such as a 5 watt radio transceiver, 50 watt stereo speaker, 40 watt amplifier, 50 kilovolt-amperes transformer, etc.)

VII. Calculating the effects of conductor resistance

A. Heat loss--Use the formulas, $P = I^2 R$ and $E = P \times \text{Time}$

EXAMPLE: A three-wire transmission line between two cities carries 100 amperes at 13.8 kV in each line. The resistance of each wire is calculated to be 8.5 ohms for the total distance. What is the total heat loss in killowatt-hours each hour?

Solution: $P = I^2 R$

$= 100 \times 100 \times 8.5$

$= 85$ kW

$E = P \times \text{Time}$

$= 85$ kW × 1 hr

$= 85$ kW-hrs per line

E (total) = 3 Lines × 85 kW-hrs

E (total) = 255 kW-hrs per hour

(NOTE: The example above is actually suggestive of AC power which behaves differently than DC power in some respects. Heat loss is calculated virtually the same however. AC power is considered in another unit of instruction.)

INFORMATION SHEET

B. Voltage drop–Use the formula, E = IR (Ohm's Law)

EXAMPLE: To start a gasoline powered fork-lift, a worker uses "jumper-cables" from a truck battery. The starter draws 150 amperes of current, and each cable has .025 ohms of resistance, including the end connectors. What is the voltage drop of the cables?

Solution: E = IR

= 150 A x .025 Ohms per wire x 2 wires

= 7.5 V (Voltage drop of cables)

(NOTE: The voltage was "dropped" twice in the circuit, once in each wire. Notice that if the battery was 12 volts only, 5.5 volts would be left for the starter motor.)

VIII. Reasons for using high voltage to supply electrical power to distant loads

A. Smaller conductor size will supply same power

EXAMPLE: To supply 44 kilowatts to a remote electric pump motor requires wiring of size AWG #2 at 220 volts and 200 amperes but only size AWG #12 at 1000 volts and 44 amperes.

B. There is less power loss in lines

EXAMPLE: Because heat loss is expressed as $P = I^2 R$, the transmission of 13.8 megawatts of power at 100 amperes and 138 kilovolts is 6.25 times more costly due to line loss than the same 13.8 megawatts at 345 kilovolts and 40 amperes.

C. There is less voltage drop in lines

EXAMPLE: Because voltage drop is equal to E = IR, the voltage drop of a 120-volt line at 100 amperes and .1 ohm is 10 volts. The same line would supply the same power at 240 volts and 50 amperes and have a voltage drop of 5 volts.

IX. Maximum power transfer–Maximum power transfer is accomplished when load resistance equals the internal resistance of the source of power; also called *impedance matching* (Transparency #3)

EXAMPLE: A 24-volt battery has an internal resistance of 4 ohms. If a lamp is attached with a resistance of 2 ohms, then the total circuit has 6 ohms, and I = 4 amperes, P (of the lamp) = 32 watts. If the lamp is 4 ohms, then R (total) = 8 ohms, I = 3 amperes, P (of the lamp) = 36 watts. If the lamp is 6 ohms, then R (total) = 10 ohms, I = 2.4 amperes, P (of the lamp) = 34.56 watts.

INFORMATION SHEET

X. Characteristics of a wattmeter (Transparency #4)

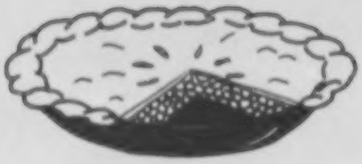
A. Current is applied to fixed coils while voltage is applied to movable coils; the meter deflection then indicates power

B. Power is measured in *real power* or *true power*

C. A wattmeter is commonly used to measure power from power lines, but it can be used for various other electrical and electronic applications

Remembering Power Formulas

$$P = IE$$



Remember "pie"

$$P = I^2R$$

(Same as $P=I\times I\times R$)

1. Recall Ohm's Law, $E=IR$

2. Recall $P=IE$

3. Replace E in "pie" with what it equals in Ohm's Law:

   $P=I(E)$ and $(E=IR)$

   $P=I(IR)$

   $P=I^2R$

Fundamental Formulas

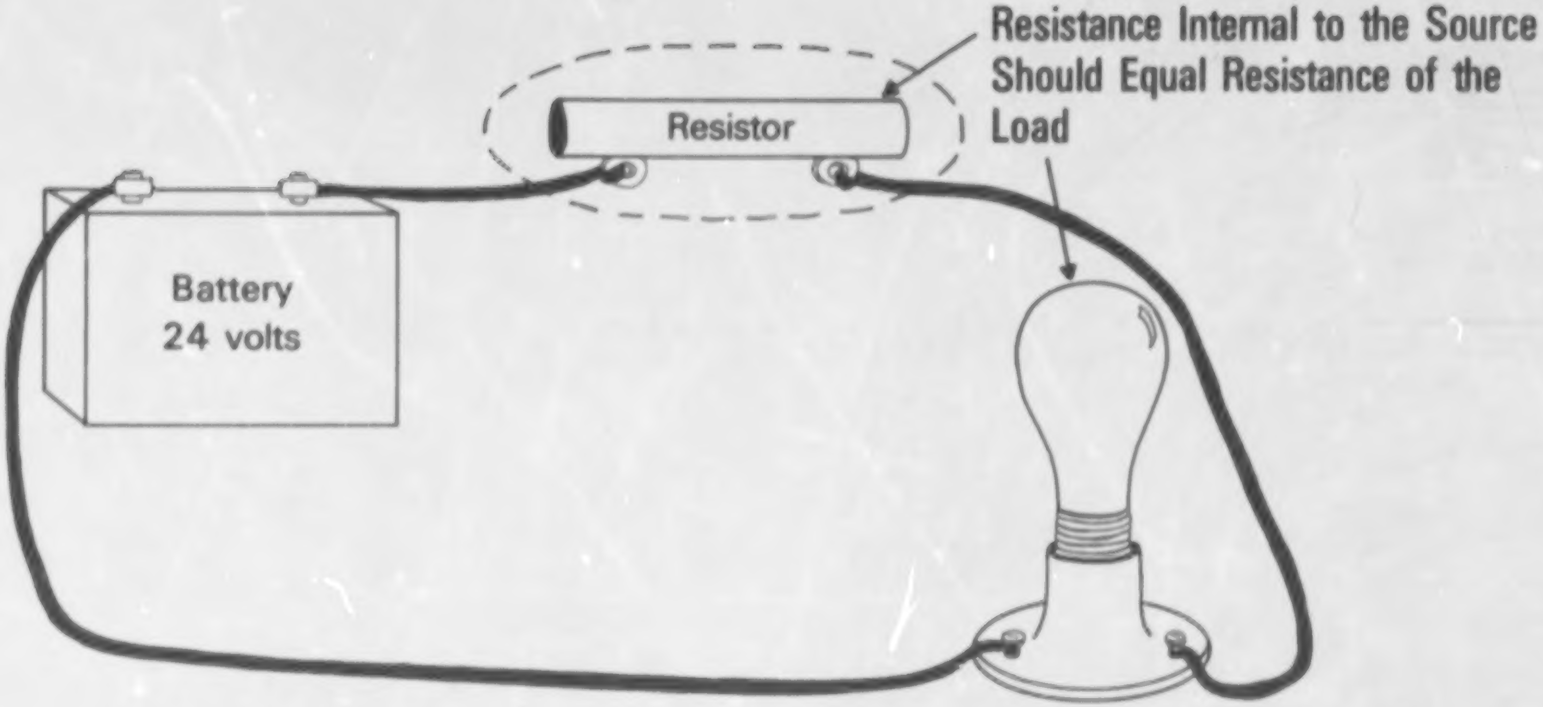
Basic: $E=IR$ $P=IE$ $P=I^2R$

Rearranged Versions: $I=\frac{E}{R}$ $I=\frac{P}{E}$ $I=\sqrt{\frac{P}{R}}$

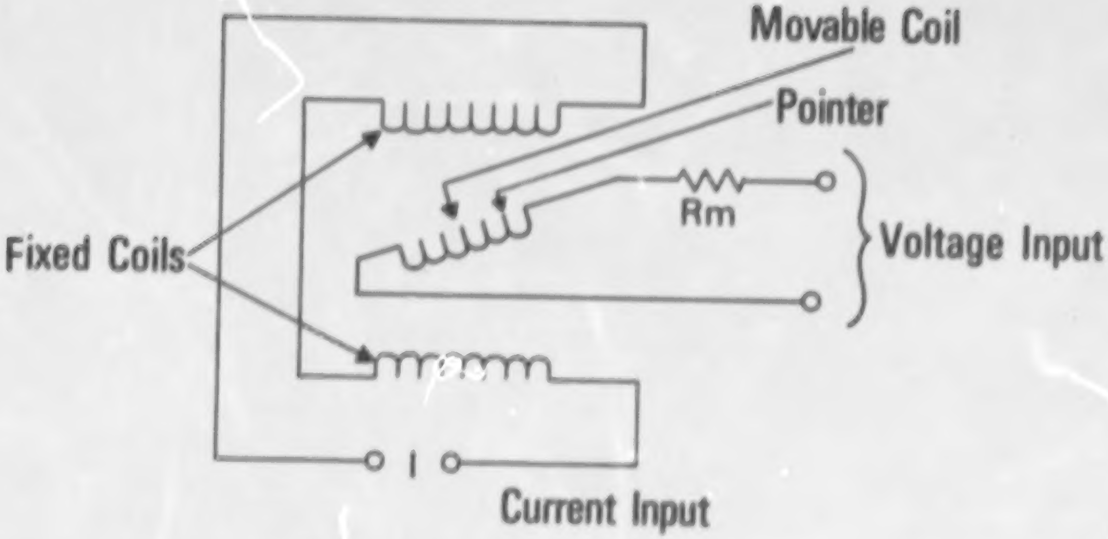
$R=\frac{E}{I}$ $E=\frac{P}{I}$ $R=\frac{P}{I^2}$

Mixed Versions:
(Not Often Used) $E=\sqrt{PR}$ $R=\frac{E^2}{P}$ $P=\frac{E^2}{R}$

Impedance Matching to Attain Maximum Power Transfer


Resistance Internal to the Source Should Equal Resistance of the Load
Resistor
Battery
24 volts

Wattmeter Diagram


Movable Coil
Pointer
Rm
Voltage Input
Fixed Coils
I
Current Input

POWER
UNIT III

ASSIGNMENT SHEET #1--CALCULATE POWER LOSS IN TRANSMISSION LINES

NAME_______________________________ SCORE___________________

Because power is equal to I x E, it is apparent that the same amount of power can be delivered through power lines as 1 ampere at 1000 volts (1000 watts) or 100 amperes at 10 volts (1000 watts). Calculate the line loss of the following problems, and answer the questions that follow.

1. A direct current solenoid operating 1000 feet away from the power supply requires 10 amperes of current. The solenoid is operating at 100 volts. The power line resistance is 3 ohms per 1000 feet.

   a. What is the solenoid's power rating?_______________________

   b. What is the power loss in the lines?_______________________

   (NOTE: The total length of wire is twice the distance.)

   c. How much power is required for the solenoid and the power lines?____________

2. The solenoid in question 1 above is replaced with a 200 volt solenoid of the same wattage rating. The power supply is readjusted, and other necessary changes are made, but the wiring remains the same.

   a. What is the ampere requirement of the 200 volt solenoid?__________________

   b. What is the power loss in the lines?_______________________

   c. The wattage of both solenoids is the same and they both would do the same work, but the amperage of the first was ____________________ times that of the second, and the power loss in the lines of the first case was ________________ times that of the second case.

   d. The power loss of the lines is considered as waste. Which solenoid is more economical to operate not considering installation costs?______________________

   ____

POWER
UNIT III

ASSIGNMENT SHEET #2--CALCULATE HEAT DEVELOPED IN EQUIPMENT

NAME______________________ SCORE______________

Unless an electrical device is a heater, any heat it develops is usually considered as wasted energy as well as potentially damaging. Calculate the heat developed in the equipment described below.

1. One connector in a power distribution panel is corroded and loose. The connector carries 100 amperes of current. If the connector has only 1 ohm of resistance, how much heat is developed inside the panel? ______________________

2. An electric oven produces heat at a rate of 6 kilowatts. Using this as a comparison, would the heat developed in the panel above be considered excessive? ____________

3. If the cost for electric power is 5¢ per killowatt-hour, how much would the wasted heat cost for a 24-hour period?______________________

POWER
UNIT III

ASSIGNMENT SHEET #3--CALCULATE VOLTAGE DROP AND POWER LOSS IN AN EXTENSION CABLE

NAME________________________________ SCORE________________

It is often necessary for workers to connect equipment to distant power receptacles by using long extension cables. Answer the following questions concerning the operation of a drill motor using a 500 foot extension cable of AWG #16 copper wire with a resistance of 6.5 ohms per 1000 feet.

1. What is the total resistance of the extension cable?____________________________

   (NOTE: The current must go to the drill motor and also return.)

2. If the drill motor draws 5 amperes, what is the voltage drop in the cable?__________

3. What is the power loss rate in the cable while the drill is operating?______________

ASSIGNMENT SHEET #3

4. If the drill should not be operated on less than 95 volts, and the cable is attached to a 115 volt receptacle, should the drill be operated?______________________

5. At what voltage is the drill operating?____________________________

6. If the drill requires 412.5 watts of power to do the work and is operating at 5 amperes, is it drawing more or less current than it would at 115 volts?_______________

7. How much current would the drill require if it operated on 412.5 watts at 115 volts?
____

(NOTE: $P = IE$; therefore, $I = \frac{P}{E}$.)

ASSIGNMENT SHEET #3

8. If the 5 amperes of lower voltage is less than one-and-one-half times the normal current, why would the drill produce almost twice the usual heat?____________________

____

____

____

____

____

9. Circle the correct answers.

   Motors operating at reduced voltages will draw (MORE or LESS) current and will operate with (MORE or LESS) heat.

POWER
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. a. 1,000 W
   b. 600 W
   c. 1,600 W
2. a. 5 A
   b. 150 W
   c. Two, four
   d. The 200-volt solenoid, or second solenoid

Assignment Sheet #2

1. 10 kW
2. Yes
3. $12.00

Assignment Sheet #3

1. 6.5 Ω
2. 32.5 V
3. 162.5 W
4. No
5. 82.5 V
6. More
7. 3.59 A
8. Answer should mention the $P = I^2 R$ relationship or that the power is related to the current multiplied times itself
9. More, more

POWER
UNIT III

JOB SHEET #1--MEASURE POWER TO A LAMP

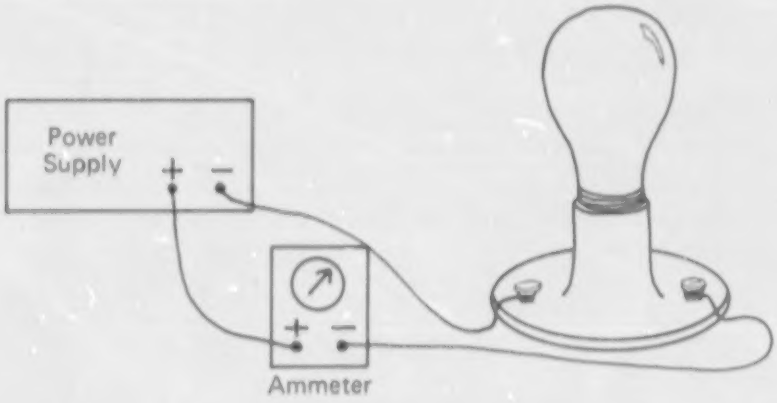
I. Equipment and materials

- A. Lamp socket
- B. Lamps--2, rated at 120 volts, 40 to 100 watts
- C. Multimeter--Capable of at least 1 ampere at 120 volt measurements
- D. DC Power Supply--Capable of an output from 0-100 VDC
- E. Wattmeter
- F. Test leads

II. Procedure

- A. Be sure power supp[illegible] is turned off
- B. Connect the circui[illegible]igure 1)

FIGURE 1



(NOTE: Have the instructor check your circuit before continuing.)

- C. Be sure power supply voltage adjust is fully counterclockwise before proceding

  (CAUTION: Any voltage can be dangerous.)

JOB SHEET #1

D. Turn on power supply and adjust voltage for 85 VDC

E. Measure the voltage at the connections across the light socket

F. Record results

Volts = ______________________________

G. Take a current reading from the ammeter in the circuit

H. Record results

Current = ______________________________

I. Turn off power

J. Calculate the power utilized by using the power formula

K. Record results

Watts = ______________________________

L. Connect wattmeter in circuit

(NOTE: Follow directions given you by the instructor.)

M. Record reading below

Watts = ______________________________

N. Insert second bulb into socket of some other wattage rating

O. Repeat steps E through M

P. Record readings below

Voltage = ______________________________

Current = ______________________________

Watts = ______________________________

Wattmeter reading = ______________________________

Q. Turn off equipment

(NOTE: Discuss your answers with your instructor.)

R. Put equipment and materials away

POWER
UNIT III

JOB SHEET #2--DETERMINE THE MAXIMUM POWER TRANSFER POINT ON A RESISTOR CIRCUIT

I. Equipment and materials

   A. DC power supply

   B. Fixed resistor--200 ohms, 1/2 watt or more

   C. Variable resistor (potentiometer)--0 to 400 ohms, or as high as 0 to 1000 ohms, 1/2 watt or more

      (NOTE: A potentiometer is often referred to as a *pot*.)

   D. Multimeter

   E. Ammeter

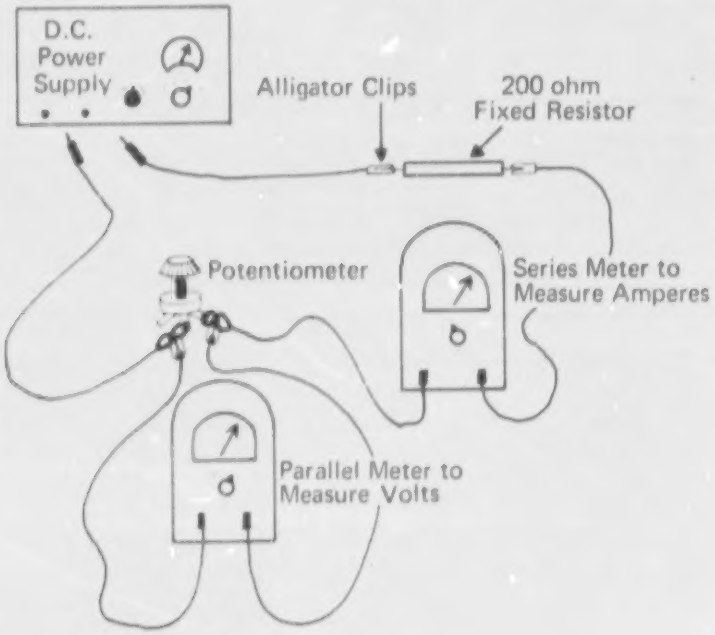
   F. Test leads

II. Procedure

   A. Connect the two meters, fixed resistor, and potentiometer as shown below (Figure 2)

      (NOTE: Do not connect to the power supply at this time.)

FIGURE 2


D.C.
Power
Supply
Alligator Clips
200 ohm
Fixed Resistor
Potentiometer
Series Meter to
Measure Amperes
Parallel Meter to
Measure Volts

JOB SHEET #2

B. Turn on the disconnected power supply and adjust the output for 10 volts

C. Turn power supply off

D. Set the ammeter to measure 0.05 amperes DC, somewhere near the limit of the scale

E. Set the multimeter to measure from zero to 10 volts DC

(NOTE: Have instructor check your circuit, both multimeter settings, and the power supply settings.)

F. Connect the circuit

G. Turn on the power supply

H. Vary the potentiometer from zero ohms (where the voltage of the parallel meter will be zero) increasing by 1-volt increments until the table below is completed

I. Record the indication of the series meter at each increment

(NOTE: Do not allow meters to go beyond a full scale indication.)

DATA TABLE

ADJUST	READ	CALCULATE
Parallel Meter Readings (Volts)	Series Meter Readings (Amps)	Power to the Potentiometer P=IE (Watts)
0		
1		
2		
3		
4		
5		
6		
7		

JOB SHEET #2

J. Find the reading in the last column of the table where the wattage value was the greatest

(NOTE: This is the maximum power transfer to the potentiometer.)

K. Turn power supply off

(NOTE: Show your results to the instructor.)

L. Put equipment and materials away

POWER
UNIT III

TEST

NAME__________________________ SCORE__________________

1. Match terms associated with DC power to their correct definitions. Write the correct numbers in the blanks.

_____a. Point where internal resistance of the load is equal to the resistance of the source or supplier of power; point of match impedance

_____b. One thousand volts

_____c. One thousand watts

_____d. Equipment or devices being supplied power

_____e. Total opposition of a device or circuit to current flow; accounts for all alternating current and direct current effects

_____f. Rate of doing work; expressed in units of watts or joules per second

_____g. Give off heat by radiation, conduction, and convection

_____h. One million watts

_____i. Voltage reduction, usually due to resistance

_____j. Power wasted in electrical wires due to heating caused by electrical current flow; heat loss of lines

_____k. Resistance that is part of the internal electrical, chemical, and mechanical workings of an electrical device; considered a single resistor

_____l. One one-thousandth of a watt

_____m. Amount of work; product of power and time, usually expressed in kilowatt-hours

_____n. Component of apparent power that represents true work; expressed in watts, it is equal to volt-amperes multiplied by the power factor

1. Electrical power
2. Milliwatt
3. Kilowatt
4. Megawatt
5. Electrical energy
6. Dissipate heat
7. Real power
8. Load
9. Line loss
10. Kilovolt
11. Voltage drop
12. Internal resistance
13. Impedance
14. Maximum power transfer point

TEST

2. Match abbreviations associated with electrical power to their correct definitions. Write the correct numbers in the blanks.

_____a. Joule

_____b. Ampere

_____c. Kilovolt

_____d. Milliwatt

_____e. Volt

_____f. American wire gauge

_____g. Volts direct current

_____h. Kilowatt-hour

_____i. Kilowatt

_____j. Direct current

_____k. Alternating current

_____l. Ohm

_____m. Meter resistance

_____n. Volts alternating current

_____o. Megawatt

_____p. Watt

_____q. Voltage; energy

1. mW
2. kW
3. MW
4. kW-hr
5. kV
6. DC
7. AC
8. W
9. V
10. A
11. VDC
12. VAC
13. J
14. Ω
15. AWG
16. R_m
17. E

3. Write the formulas for electrical power in terms of amperage, voltage, and resistance.

a. Voltage and amperage-- ______________________________

b. Resistance and amperage-- ______________________________

TEST

4. Calculate electrical power from measurements of amperage, voltage, and resistance.

   a. Voltage and amperage--An electric hot water heater has a measured current use of 14 amperes while it is operating at 220 volts. What is its power consumption rate?

   Power consumption rate = ______________________________

   b. Resistance and amperage--A drill motor is being used at a remote site in a storage yard. It is connected to two twin-lead extension cables each one-hundred feet in length. The extension cords are made of wire with a resistance of 8 ohms per 1,000 feet of single conductor. If the drill is being supplied with 3 amperes, what is the power loss rate in the 400 feet of extension cable?

   Power loss rate = ______________________________

5. Calculate electrical energy used in direct current circuits in the problem below.

   An electric fork lift operates from four 24-volt batteries connected in parallel. If each battery delivers 25 amperes continuously during operation, how much power is used during one-half hour of operation?

   Power used = ______________________________

TEST

6. Match power ratings to their correct descriptions. Write the correct numbers in the blanks.

______a. Maximum power a device can dissipate without possible damage; usually much higher than the intended operating power; damage is certain at higher power operations

______b. Maximum power which a device can deliver to a load; power output in form of heat, sound, and mechanical energy; may operate at or anywhere below the output rating

______c. Power at which a device is intended to operate; probably will not operate properly at a lower power; may become damaged at a higher power operation

1. Power requirement
2. Heat dissipation
3. Power output

7. Calculate effects of conductor resistance.

(NOTE: Use the formula $P = I^2 R$ and $E = P \times \text{Time}$.)

a. A heater is made from resistance wire having a total resistance of nine ohms. The heater operates at 20 amperes. What quantity of heat does the heater supply in two hours time?

____

b. A defective connection on a large power cable has 0.2 ohms of resistance. What is the voltage drop on the 120 volt line due to the one connector if there is 80.0 amperes of current going through it?

____

TEST

8. Name reasons for using high voltage to supply electrical power to distant loads.

   a. ____

   b. ____

   c. ____

9. State how maximum power transfer is accomplished.

   ____

   ____

   ____

   ____

10. Name the characteristics of a wattmeter.

    a. ____

    ____

    b. ____

    ____

    c. ____

    ____

(NOTE: Test questions 11-14 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

11. Calculate power loss in transmission lines.

12. Calculate heat developed in equipment.

13. Calculate voltage drop and power loss in an extension cable.

14. Demonstrate the ability to

    a. Measure power to a lamp.

    b. Determine the maximum power transfer point on a resistor circuit.

POWER
UNIT III

ANSWERS TO TEST

1. a. 14
   b. 10
   c. 3
   d. 8
   e. 13
   f. 1
   g. 6
   h. 4
   i. 11
   j. 9
   k. 12
   l. 2
   m. 5
   n. 7
2. a. 13
   b. 10
   c. 5
   d. 1
   e. 9
   f. 15
   g. 11
   h. 4
   i. 2
   j. 6
   k. 7
   l. 14
   m. 16
   n. 12
   o. 3
   p. 8
   q. 17
3. a. $P = IE$
   b. $P = I^2 R$
4. a. $P = IE$

$= 15\text{ A} \times 220\text{ V}$

$= 3300\text{ W}$

   b. The 400 feet of wire has 4 x .8 ohms of total resistance or 3.2 ohms

$P = I^2 R$

$= 3 \times 3 \times 3.2$

$= 28.8\text{ W}$

ANSWERS TO TEST

5. $P = IE$

   $= 4$ batteries $\times$ 25 A each $\times$ 24 V

   $= 2400$ W

   $E = P \times \text{Time}$

   $= 2400 \times \frac{1}{2}$ hr

   $= 1200$ W-hrs

   $= 1.2$ kilowatt hours or 1.2 kW-hrs

6. a. 2

   b. 3

   c. 1

7. a. $P = I^2 R$

   $= 20 \times 20 \times 9$

   $= 3600$ W

   $E = P \times \text{Time}$

   $= 3600 \text{ W} \times 2 \text{ hrs}$

   $= 7200$ W-hrs

   $= 7.2$ kilowatt hours, or 7.2 kW-hrs

   b. $E = IR$

   $= 80.0 \times 0.2$

   $= 16$ V

8. a. Smaller conductor size will supply same power

   b. There is less power in lines

   c. There is less voltage drop in lines

9. Maximum power transfer is accomplished when load resistance equals the internal resistance of the source of power; also called *impedence matching*

10. a. Current is applied to fixed coils while voltage is applied to movable coils; the meter deflection then indicates power

    b. Power is measured in *real power* or *true power*

ANSWERS TO TEST

c. A wattmeter is commonly used to measure power from power lines, but it can be used for various other electrical and electronic applications

11. Evaluated to satisfaction of instructor
12. Evaluated to satisfaction of instructor
13. Evaluated to satisfaction of instructor
14. Performance skills evaluated to satisfaction of instructor

AC FUNDAMENTALS
UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to demonstrate the ability to compare DC voltage to AC root-mean-square voltage-meter measurements. The student should also be able to measure power to AC single-phase and three-phase motors. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with AC fundamentals to their correct definitions.
2. Match abbreviations associated with AC fundamentals to their correct definitions.
3. Identify symbols associated with AC.
4. Distinguish between advantages and disadvantages of AC compared to DC.
5. Describe the left-hand rule for generating current.
6. State how electricity is generated.
7. Label the principal parts of a generator.
8. State factors that determine frequency of generated AC.
9. Name methods of measuring frequency.
10. Identify AC waveform components.
11. Name methods of producing AC for shop use.
12. Solve problems converting from one AC measurement to another AC measurement.
13. Define three-phase power.
14. State the real power formulas for AC single-phase and three-phase circuits.
15. Convert a DC voltage to an equivalent AC voltage.
16. Calculate the power to an AC motor.
17. Calculate the power of a three-phase circuit.

OBJECTIVE SHEET

18. Convert from one voltage measurement to another.
19. Demostrate the ability to
    a. Compare DC voltage to AC, root-mean-square voltmeter measurements.
    b. Measure voltage and current to a single-phase AC motor.
    c. Measure voltage and current to a three-phase AC motor.
    d. Measure AC voltage and frequency.

AC FUNDAMENTALS
UNIT IV

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide student with objective sheet.

   B. Provide student with information, assignment and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Use a triggered oscilloscope to show three-phase AC power. Set the trigger to line, and scope each phase to show the 120° phase relationship.

   H. Provide a generator so that the students may observe brushes and other parts. An automobile generator or alternator would show the parts.

   I. Use a series circuit with a capacitor and electric light to show how DC is blocked by the capacitor and AC is not. Repeat the demonstration using a transformer.

   J. Give test.

II. Instructional materials

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM #1-The Left-hand Generator Rule
      2. TM #2-Simple AC Generator
      3. TM #3-AC Generation
      4. TM #4-Principal Generator Parts
      5. TM #5-Principal Generator Parts (Continued)
      6. TM #6-Generator Rotor with Shaft-Driven Exciter
      7. TM #7-AC Waveform Components
      8. TM #8-Three-Phase Power Waveform Relationship Diagram

SUGGESTED ACTIVITIES

D. Assignment sheets

1. Assignment Sheet #1--Convert a DC Voltage to an Equivalent AC Voltage
2. Assignment Sheet #2--Calculate the Power to an AC Motor
3. Assignment Sheet #3--Calculate the Power of a Three-Phase Circuit
4. Assignment Sheet #4--Label AC Waveform Components
5. Assignment Sheet #5--Convert from One Voltage Measurement to Another

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1--Compare DC Voltage to AC, Root-Mean-Square Voltmeter Measurements
2. Job Sheet #2--Measure Voltage and Current to a Single-Phase AC Motor
3. Job Sheet #3--Measure Voltage and Current to a Three-Phase AC Motor
4. Job Sheet #4--Measure AC Voltage and Frequency

G. Test

H. Answers to test

III. Unit references

A. Alerich, Walter N.. *Electricity 3.* Albany, New York: Delmar Publishers, 1974.

B. Seippel, Robert G. *Alternating Current Circuit Analysis.* Chicago: American Technical Society, 1975.

AC FUNDAMENTALS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Alternating current–Voltage that continuously varies in magnitude and periodically reverses direction

EXAMPLE: Sixty (60) hertz power changes direction 120 times per second.

B. Polarity--Direction of electrical current flow; potential or tendency to flow; magnetic direction

EXAMPLE: Polarity of most automobiles is such that the negative terminal is attached to the frame or chassis.

C. Root-mean-square--Mathematical term for AC or voltage expressed as a value that compares to DC or voltage effectiveness

EXAMPLE: Standard household power is about 120 volts AC, root-mean-square; voltage actually reaches peaks of almost 170 volts.

D. Average value--Average of the waveform amperage or voltage which is not equal to the peak value or the root-mean-square value

EXAMPLE: 120 volts AC, root-mean-square averages about 108 volts

E. Hertz--Cycles per second

EXAMPLE: 60 hertz = 60 cycles per second

(NOTE: Sixty hertz power was chosen as a standard in the United States many years ago. Four hundred hertz actually is more efficient in many ways and might have been a better choice if more were known about electrical power at that time.)

F. Cycles per second--Frequency; interpretation for the term *hertz*; rate at which basic waveform is repeated

EXAMPLE: Sixty (60) cycles per second AC repeats the process of surging current, first in one direction then the other, at a rate of 60 times each second.

G. Phase--Relating to a point in the cycle of one AC waveform compared to another AC waveform or compared to time; an AC source or conductor

EXAMPLES: Two AC voltages from different sources may be "out of phase" or "in phase" with each other; ordinary household power is "single phase."

INFORMATION SHEET

H. Wave length--Distance an AC waveform travels during the time of one cycle

EXAMPLE: Sixty (60) hertz current could travel about 1,500 miles during 1/60 of a second or during one cycle

I. Armature--Assembly of a generator which supplies the output; may be rotating or stationary, or assembly of an electric motor that is forced to move; center or outside assembly may rotate

J. Field--Coils and magnets that supply the magnetic field for a generator or motor armature; may rotate or be stationary; any area where magnetic force is concentrated

K. Pole--One end of a magnet; a section of a generator or motor that produces magnetism or electrical current

L. Commutator--Divided ring on a motor or generator rotor that acts as a rotating switch that selects and exchanges current between the rotor poles and outside circuits

(NOTE: Commutators are common to DC generators [exciters] and various types of AC and DC motors. AC generators and certain motors have slip rings.)

M. Power factor--Mathematical figure that represents a measure of how well voltage and amperage are working in unison

EXAMPLE: A power factor of .9 indicates a circuit wherein current and voltage are not acting at the exact same time as they would be if the power factor were 1.

(NOTE: Power factor, real power, imaginary power, phase angle, reactive power, and vector diagrams are considered in later units.)

N. Exciter--DC generator or DC power source that provides power to the field magnets of a generator

O. Kilowatt--One thousand watts

EXAMPLE: 5.4 kilowatts = 5,400 watts

P. Alternation--One half of a cycle, either positive or negative

Q. Cycle--Change of an alternating waveform from zero to a negative peak, back through zero to a positive peak, and back to zero

R. Oscilloscope--Instrument that produces an image of voltage on a cathode-ray tube screen

S. Frequency counter--Instrument in which frequency can be measured directly without conversion through the use of digital display

T. Amplitude--Peak height of the AC sine wave; measured in volts

INFORMATION SHEET

II. Abbreviations associated with AC fundamentals

- A. **AC**--Alternating current
- B. **DC**--Direct current
- C. **rms**--Root-mean-square
- D. **Hz**--Hertz
- E. **cps**--Cycles per second
- F. **Ph**--Phase
- G. **Cyc**--Cycle
- H. **Freq**--Frequency
- I. **V**--Volt
- J. **rpm**--Revolutions per minute
- K. **N**--North magnetic pole
- L. **S**--South magnetic pole
- M. P_f--Power factor
- N. **kW**--Kilowatt
- O. **Pk**--Peak
- P. **Pk-Pk**--Peak-to-peak
- Q. **Eff**--Effective
- R. **Ave**--Average

III. Symbols associated with AC fundamentals

- A. Alternating waveform, AC-- ∼
- B. Phase-- ϕ
- C. Wave length-- λ

INFORMATION SHEET

D. Positive polarity indicator--+

E. Negative polarity indicator--−

IV. Advantages and disadvantages of AC compared to DC

A. Advantages

1. Is simple, economical to produce

EXAMPLE: A generator or alternator produces AC directly as it rotates. A DC generator or alternator involves more parts, such as commutator segments or rectifiers and filtering devices. These make DC generators more expensive to buy and maintain.

2. Can be readily transformed to higher or lower voltages

EXAMPLE: AC can be converted through transformers to higher or lower voltages while DC cannot.

3. Can radiate high frequency over distances without conductors

EXAMPLES: Radio waves, microwaves, radar

4. Can be used to drive synchronous motors

EXAMPLE: AC motors and generators are more simply constructed.

5. Are less expensive in large motors than in equivalent other types of current motors

EXAMPLE: AC motors are more simply constructed, as are DC generators.

B. Disadvantages

1. Must be stored indirectly

EXAMPLE: DC can be stored temporarily in batteries or capacitor.

2. Must operate variable speed motors indirectly

EXAMPLE: DC motors can vary speed with simple controls, while AC must be converted to other forms before application to variable speed motors.

3. Does not always work with voltage for best efficiency

EXAMPLE: AC reacts to certain circuit characteristics by delaying current or voltage, so that the two are not working exactly in unison.

INFORMATION SHEET

4. May hum and vibrate at low frequencies

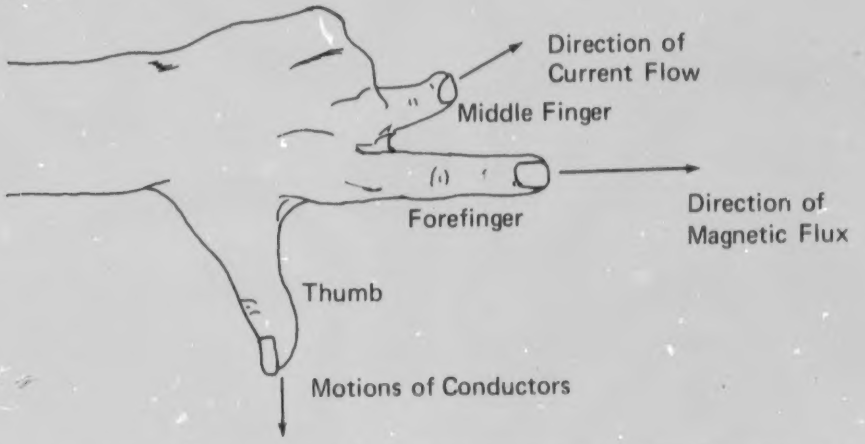
   EXAMPLES: Fluorescent light fixtures may hum annoyingly; large transformers and equipment may vibrate.

5. Require DC in many industrial applications

   EXAMPLES: Electrochemical processes, such as electroplating, battery charging, telephone systems, electrostatic processes, variable speed motors

V. Left-hand rule for generating current--Make thumb, index finger, and middle finger of the left hand all point at right angles to each other. If the motions of the conductors are indicated by the thumb, and the direction of the magnetic field is indicated by the index finger, then the middle finger will point in the direction of electron current flow (Transparency #1; Figure 1)

FIGURE 1



VI. Generating electricity--Electricity is generated when motion occurs at right angles between conductors of a complete circuit and a magnetic field (Transparencies #1, #2, and #3)

EXAMPLE: AC waveform corresponding to generator armature positions (Transparencies #2 and #3)

A. With conductors moving parallel with the magnetic field, there is no electricity generated

B. With conductors moving at a 45° angle to the field, output is .707 times its maximum value

C. When conductors are at right angles to the field, peak output is generated

INFORMATION SHEET

D. As conductors are again at a 45° angle to the field, output drops to .707 times the peak

E. When conductors are again moving with the field, output returns to zero

F. As conductors move at a 45° angle to the field but in the opposite direction, output is reversed and is .707 times the negative peak value

G. At right angles to the field, conductors' motion will cause the output to be at the maximum, but the direction is opposite

H. As conductors are again at a 45° angle to the field, output drops to .707 times the negative peak

I. When conductors have returned to the initial position, one 360° revolution has been made, one cycle has been generated, and for a 3,600 rpm generator, 1/60 of a second has passed

VII. Principal generator parts

A. Generators with separate exciters (Transparencies #4 and #5)

1. Stator
    - a. Windings
    - b. Poles
    - c. Frame
2. Rotor
    - a. Windings
    - b. Poles
    - c. Slip rings
3. End bell
    - a. Bearing
    - b. Brush rigging
    - c. Brushes

(NOTE: Stator is the assembly that is stationary, and the rotor is that which rotates; either may be the field or the armature.)

INFORMATION SHEET

B. Generator rotors with shaft-driven exciters (Transparency #6)

1. Generator section

a. Brushes

b. Slip rings

c. Windings

d. Poles

2. Exciter section

a. Brushes

b. Commutator

c. Windings

d. Poles

VIII. Factors that determine frequency of generated AC

A. Number of magnetic field and armature poles

B. Speed of rotation

IX. Methods of measuring frequency

A. Using an oscilloscope

(NOTE: This method uses an instrument that produces an image of voltage on a cathode-ray tube screen.)

B. Using a frequency counter

(NOTE: This method uses an instrument in which frequency can be measured directly without conversion through the use of a digital display.)

X. AC waveform components (Transparency #7)

A. One cycle

B. One generator revolution

(NOTE: This dimension is shown for a two-pole generator.)

C. One alternation

D. Positive peak

E. Root-mean-square (effective value)

INFORMATION SHEET

F. Average

G. Zero reference line

H. Negative peak

I. Generator rotor position degrees

(NOTE: This dimension is shown for a two-pole generator; see Transparencies #2 and #3)

J. Zero-to-peak (positive)

K. Zero-to-peak (negative)

L. Peak-to-peak

XI. Methods of producing AC for shop use

A. Use an AC power supply

(NOTE: It was stated earlier that AC is produced through a generation system, but a method must be available to regulate this AC for a higher or lower output.)

B. Use a function generator

(NOTE: Often an AC wave–other than a sine wave--is necessary. Through the use of a specific circuitry, these outputs are available.)

XII. Formulas for converting from one AC measurement to another AC measurement (Transparency #7)

(NOTE: Meters automatically measure effective voltage, amperage, or power, and conversion is not necessary. Oscilloscopes show peak-to-peak values; however, components are sometimes rated at maximum instantaneous current or voltage rather than at an effective value. For these reasons, it is sometimes necessary to convert values.)

A. Convert from a Pk-Pk voltage to a Pk voltage--Use the formula $\text{Pk} = \frac{\text{Pk-Pk}}{2}$

(NOTE: Peak voltage is one-half of the Pk-Pk voltage.)

EXAMPLE: A voltage display on an oscilloscope indicates a Pk-Pk voltage of 340 volts

$$\text{Pk} = \frac{\text{Pk-Pk}}{2}$$

$$= \frac{340\text{ V}}{2}$$

$$= 170\text{ V}$$

INFORMATION SHEET

B. Convert from Pk to Pk-Pk voltage--Use the formula Pk-Pk = P x 2

(NOTE: Pk-Pk voltage is twice the amount of peak voltage.)

EXAMPLE: Using the Pk voltage above of 170 volts

Pk-Pk = Pk x 2

= 170 V x 2

= 340 V

C. Convert Pk-Pk voltage to effective voltage--Use the formula Eff = Pk x .707

(NOTE: Effective voltage is a root-mean-squared value of peak voltage.)

EXAMPLE: Using the value above of 340 volts, Pk-Pk must be converted to a Pk voltage as in A; then this Pk value is used to convert to effective voltage.

Eff = Pk x .707

= 170 V x .707

= 120 V

D. Convert effective voltage to Pk-Pk voltage--Use the formula Pk = Eff x 1.414

EXAMPLE: Using the value above of 120 volts, first calculate for the Pk voltage, then for Pk-Pk voltage.

Pk = Eff x 1.414

= 120 V x 1.414

= 169.7 V or 170 V

Pk-Pk = Pk x 2 or 170 V x 2

= 340 V

E. Convert Pk-Pk voltage to average voltage--Use the formula Ave = Pk x .636

(NOTE: Average voltage is the average of one alternation or a value of .636 of the peak voltage.)

EXAMPLE: Using the Pk-Pk value above of 340 volts, find the Pk value which is 170 volts. Then calculate for the average voltage.

Ave = Pk x .636

= 170 V x .636

= 108 V

INFORMATION SHEET

F. Convert the average voltage to a Pk-Pk value--Use the formula Pk = Ave x 1.572

EXAMPLE: Use the average value above of 108 volts

Pk = Ave x 1.572

= 108 V x 1.572

= 170 V

Pk-Pk = Pk x 2

= 170 V x 2

= 340 V

XIII. Three-phase power--Three AC waveforms from a common source, such that each peaks 120° apart, and each is conducted on a separate line (Transparency #8)

(NOTE: AC power can be generated in any number of phases and connected by several wiring arrangements.)

XIV. Real power formulas for AC single-phase and three-phase circuits

A. Single-phase--Use the formula $P = IEP_f$

(NOTE: The letter I is the effective or root-mean-square current, the letter E, is the effective or root-mean-square voltage, and the power factor is 1 or less depending on the characteristics of the circuit. The power factor is used to determine the "real power" of a circuit as opposed to the "apparent power.")

EXAMPLE: A single-phase AC motor requires 6 amperes at 120 volts, and the power factor is known to be .8

$P = IEP_f$

= 6 A x 120 V x .8

= 567 W (real power)

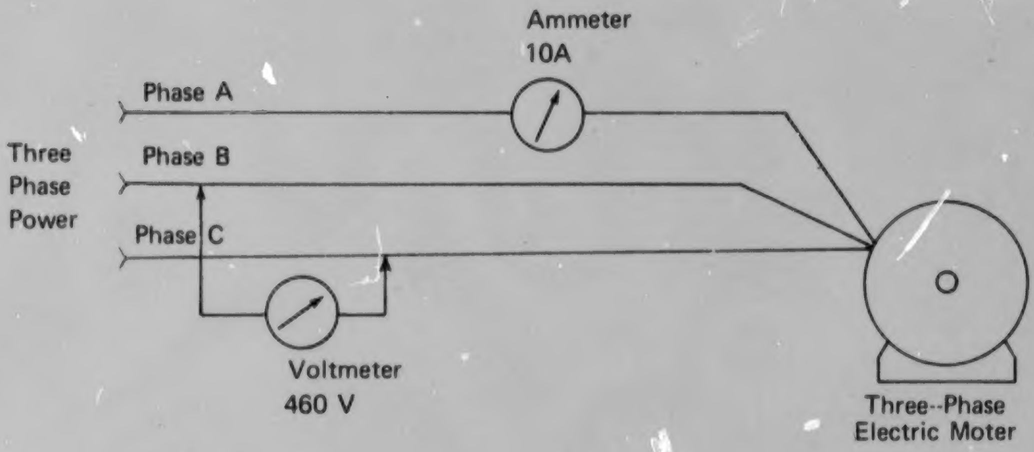
INFORMATION SHEET

B. Three-phase--Use the formula, $P = IE\sqrt{3}P_f$

(NOTE: The letter I is the current in any one of the three primary conductors and is assumed to be the same as the other two. The letter E is the voltage measured between two primary conductors and is assumed to be the same, if measured between any two.)

EXAMPLE: Three-phase power supplied to a motor has current and voltage as indicated in Figure 2.

FIGURE 2


Ammeter
10A
Phase A
Three
Phase
Power
Phase B
Phase C
Voltmeter
460 V
Three--Phase
Electric Moter

Power supplied to the motor is calculated as follows:

$P = IE\sqrt{3}P_f$

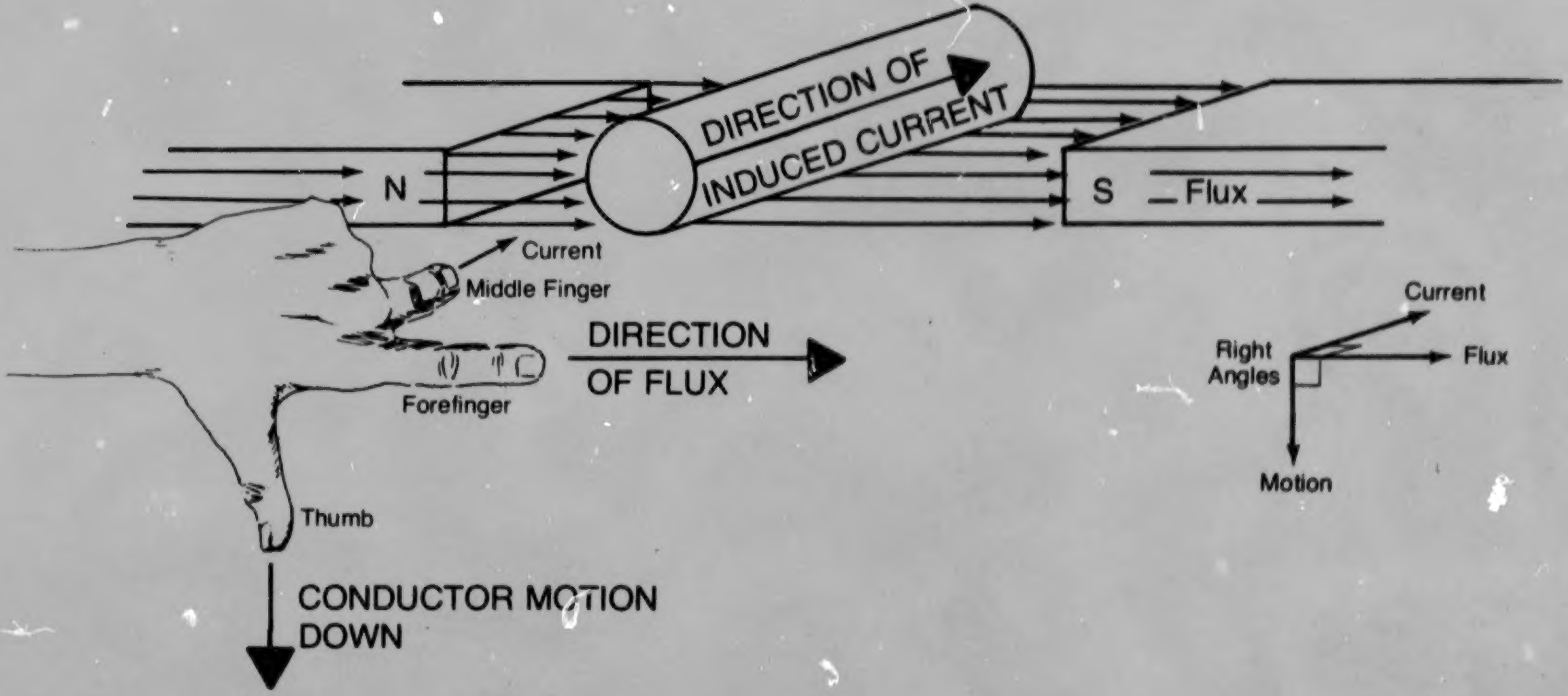
$= 10\text{ A} \times 460\text{ V} \times 1.732 \times 1.0$

(NOTE: Power factor for this motor circuit is assumed to be 1.)

$= 7967.2\text{ W}$

$= 7.97\text{ kW}$ (real power)

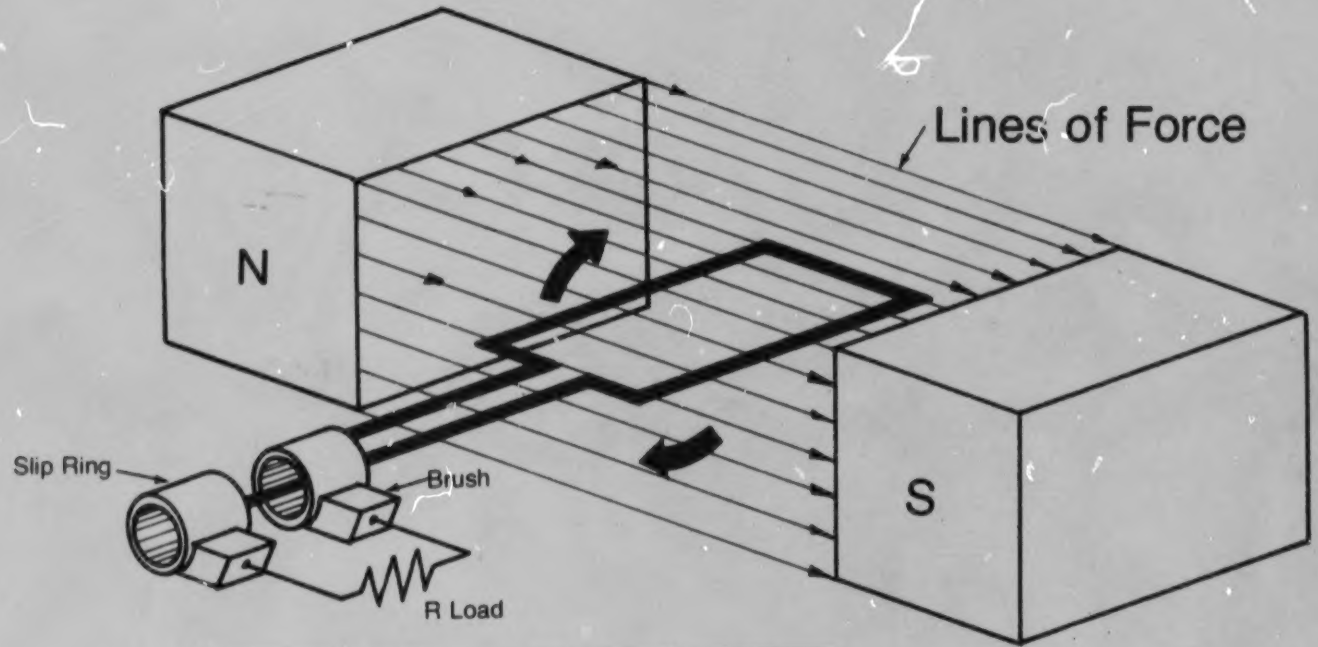
The Left Hand Generator Rule

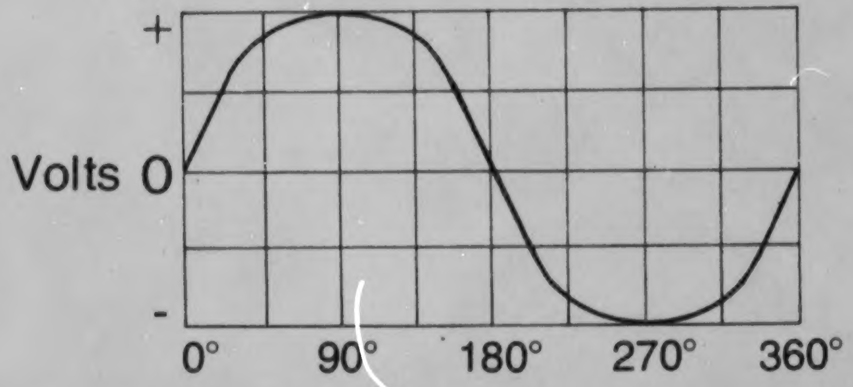

DIRECTION OF
INDUCED CURRENT
N
S
Flux
Current
Middle Finger
DIRECTION
OF FLUX
Forefinger
Thumb
CONDUCTOR MOTION
DOWN
Current
Right
Angles
Flux
Motion

TM #1

IIEE - 173-C

Simple A C Generator


Lines of Force
N
S
Slip Ring
Brush
R Load

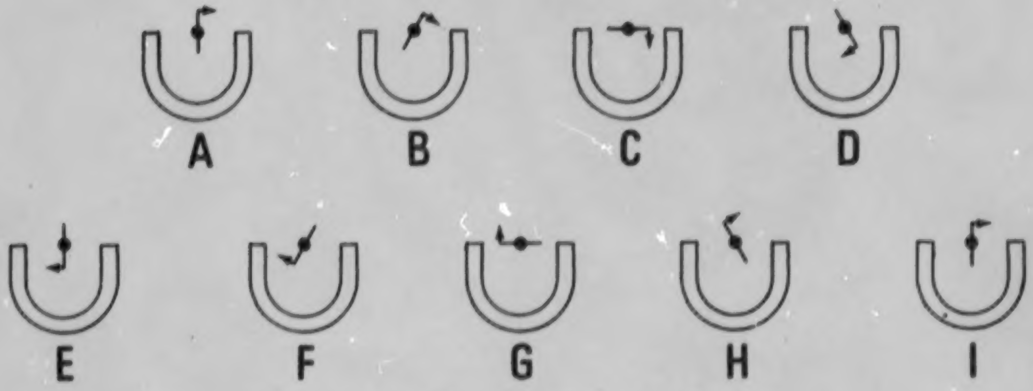


[Loop Shown in
Maximum Voltage Position]

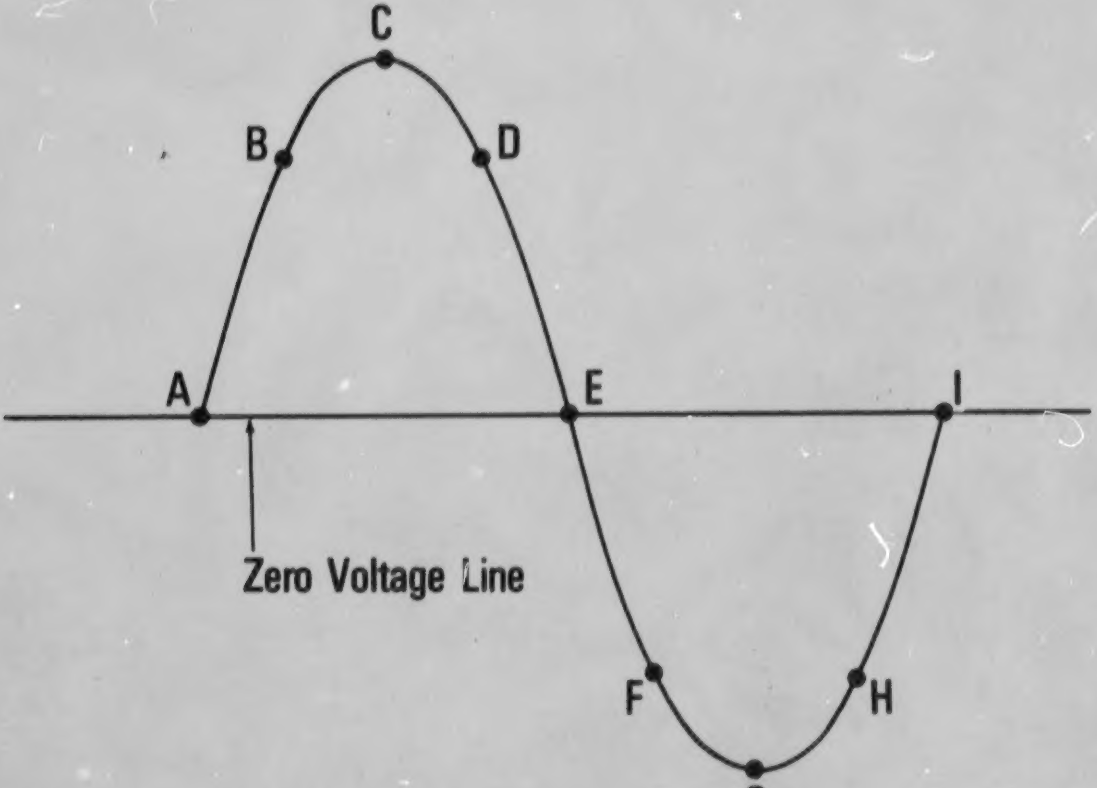
TM #2

AC Generation

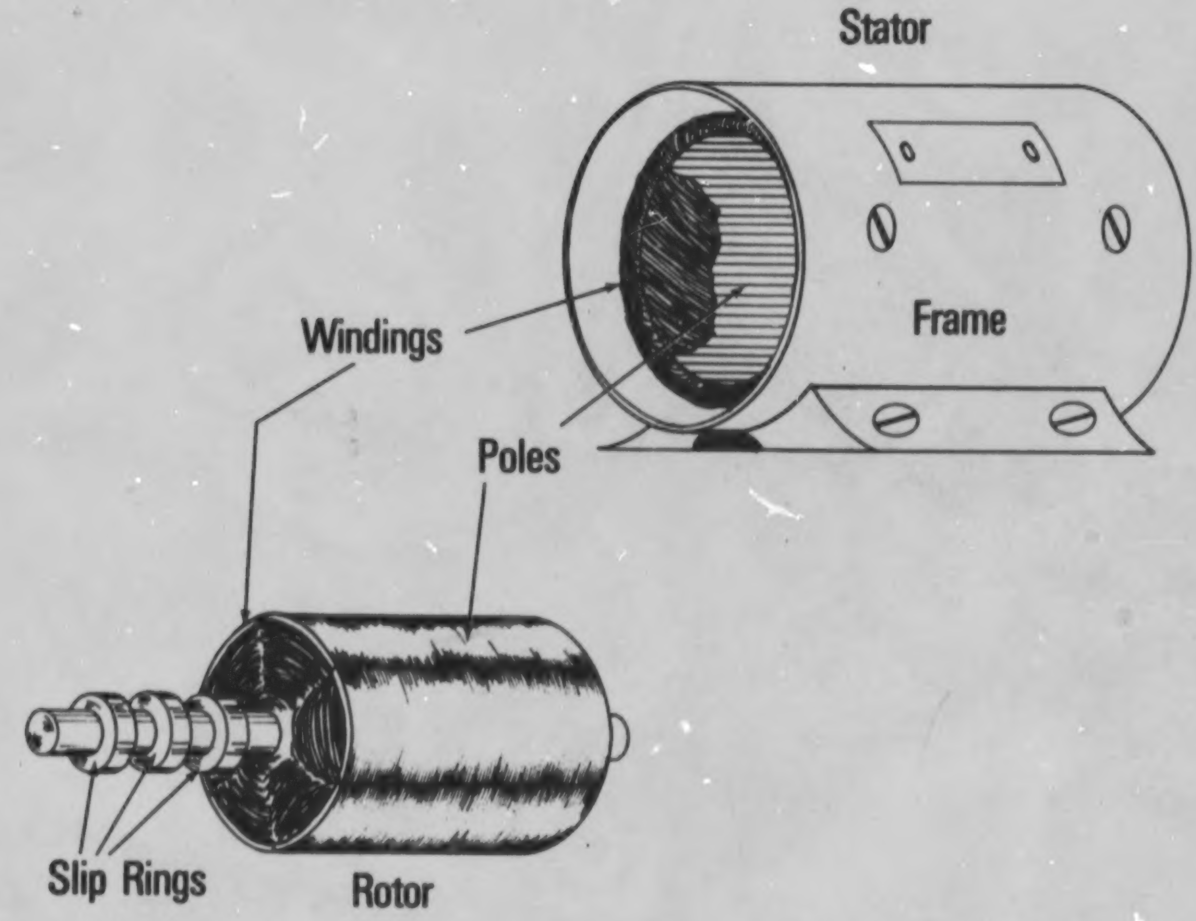
Indicated Rotor Generator Positions



Corresponding Waveform Points

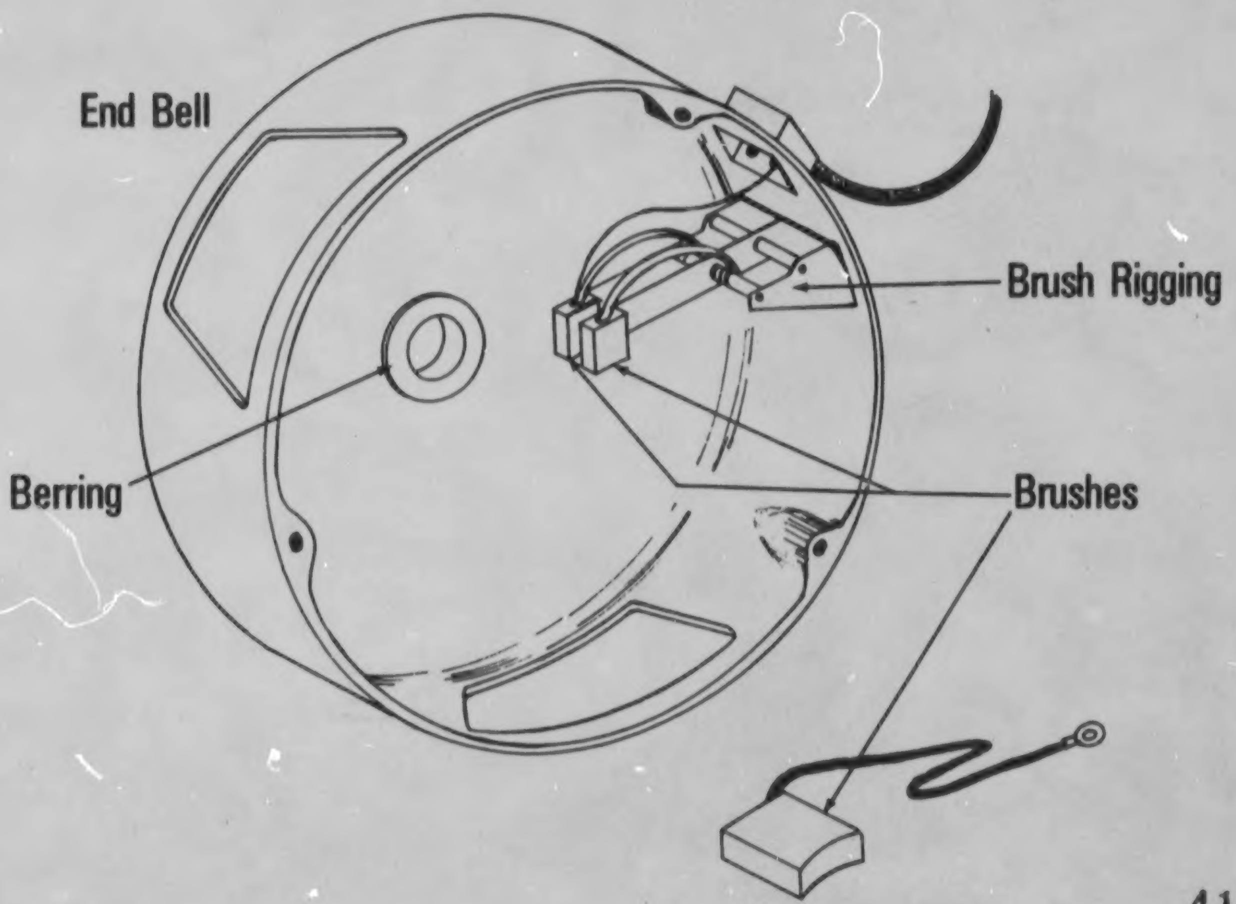

C
B
D
A
E
I
Zero Voltage Line
F
H
G

Principal Generator Parts

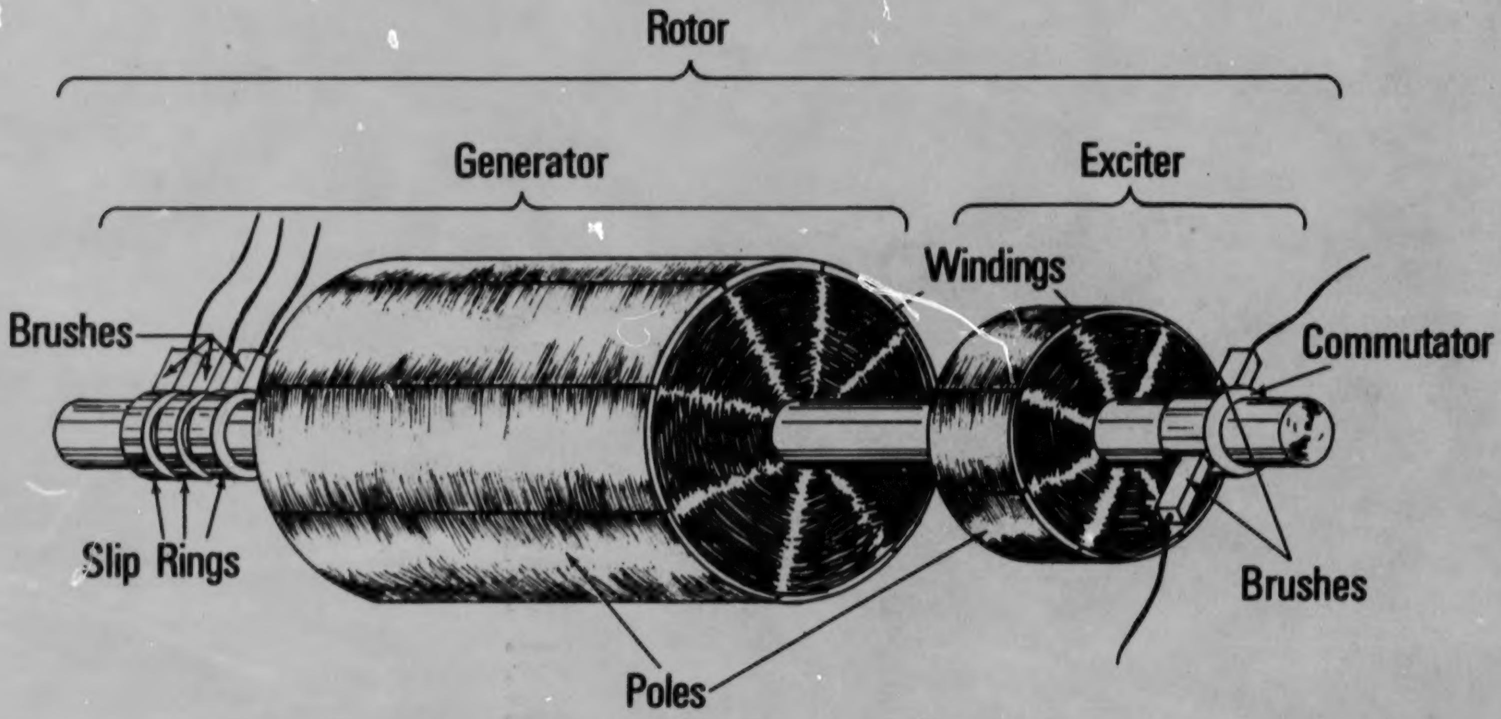

Stator
Windings
Frame
Poles
Slip Rings
Rotor

Principal Generator Parts

(Continued)


End Bell
Brush Rigging
Berring
Brushes

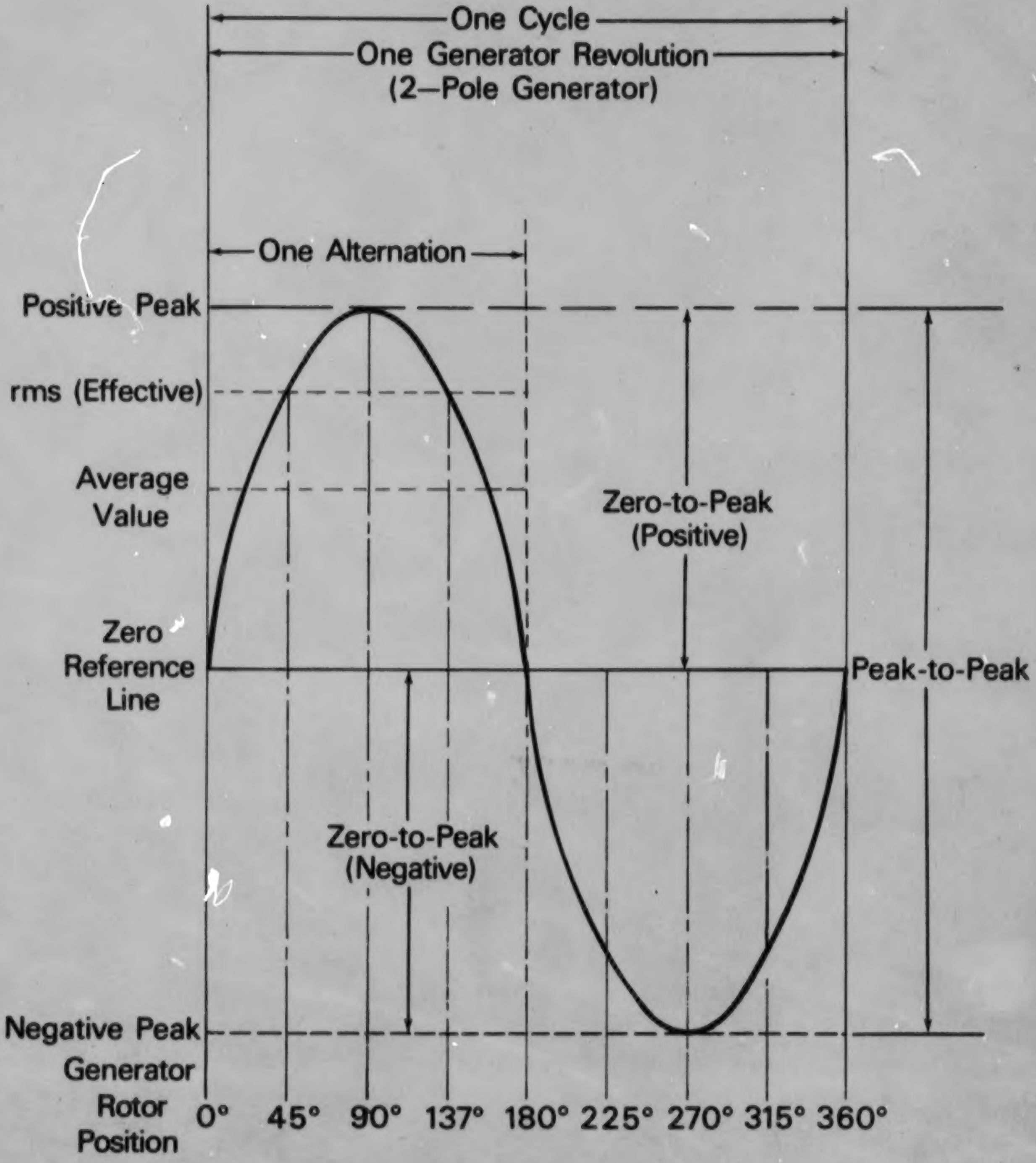
Generator Rotor With Shaft-Driven Exciter


Rotor
Generator
Exciter
Windings
Brushes
Commutator
Slip Rings
Brushes
Poles

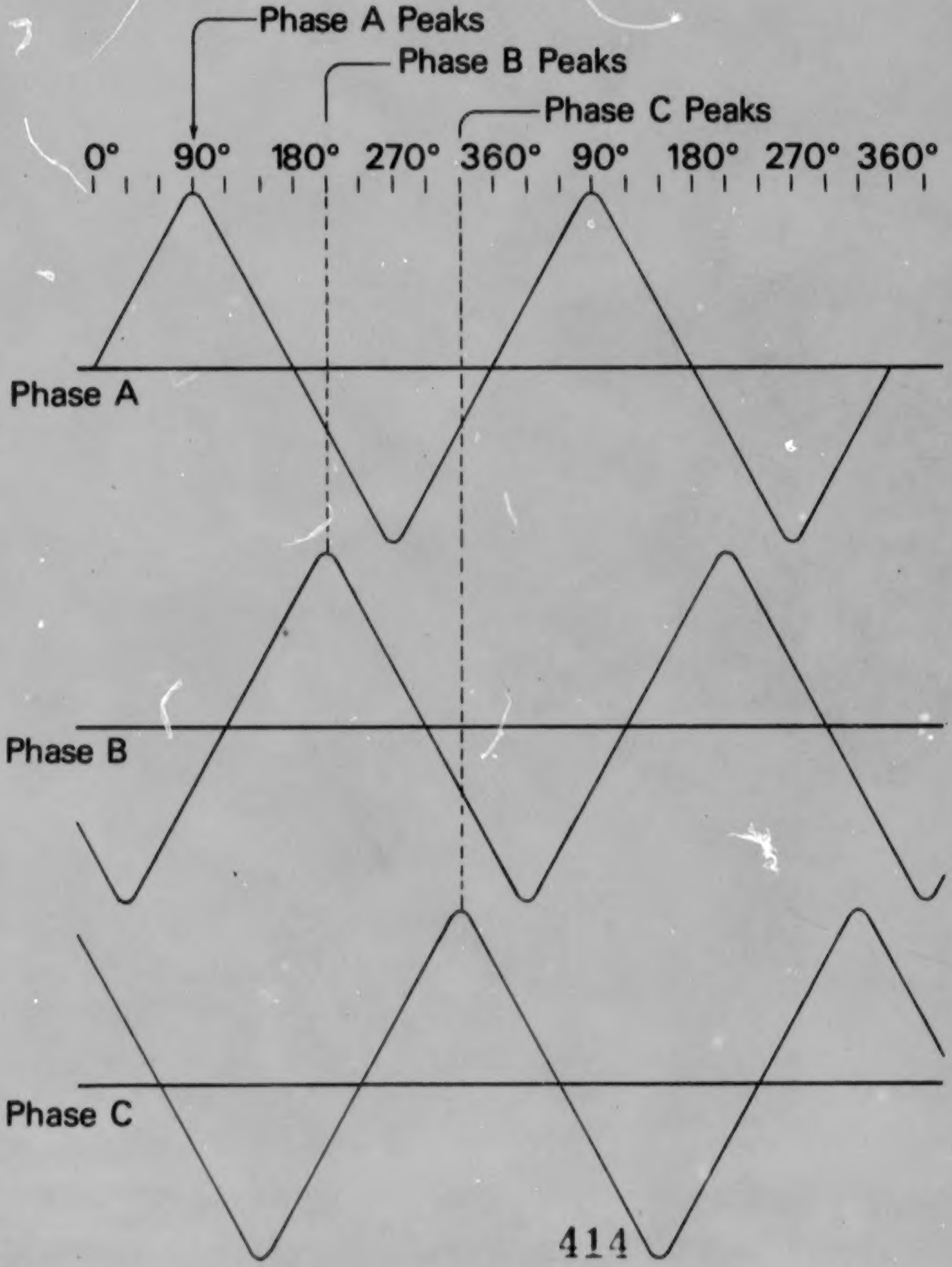
411

412

AC Waveform Componets


One Cycle
One Generator Revolution
(2—Pole Generator)
One Alternation
Positive Peak
rms (Effective)
Average Value
Zero Reference Line
Negative Peak
Zero-to-Peak (Positive)
Zero-to-Peak (Negative)
Peak-to-Peak
Generator Rotor Position
0°
45°
90°
137°
180°
225°
270°
315°
360°

Three-Phase Power Waveform Relationship Diagram


Phase A Peaks
Phase B Peaks
Phase C Peaks
0°
90°
180°
270°
360°
90°
180°
270°
360°
Phase A
Phase B
Phase C

AC FUNDAMENTALS
UNIT IV

ASSIGNMENT SHEET # 1--CONVERT A DC VOLTAGE TO AN EQUIVALENT AC VOLTAGE

NAME________________________ SCORE ____________

A technician has determined that 50 volts DC will operate a device at 2 amperes of current. The device is to be changed to one that operates on AC, but at the same 2 amperes of current.

1. What peak-to-peak AC voltage will do the same job?________________

   (NOTE: AC effective power is equal to the DC power. Also, unless stated otherwise, the power factor is assumed to be 1.)

2. What is the power required by the device?________________

   (NOTE: The same power is required regardless of whether AC or DC is used to operate either device.)

AC FUNDAMENTALS
UNIT IV

ASSIGNMENT SHEET #2--CALCULATE THE POWER TO AN AC MOTOR

NAME______________________________ SCORE ______________

AC motors are often rated at two voltages, such as 120/240 or 230/460. Motor winding wiring is reconnected to change the motor operating voltage to one that will suit the needs of the user. Calculate the power requirement of the following motors, and answer the subsequent questions.

1. A new motor is rated, 120/240 volts AC, 1ϕ. The electrician has determined that it will operate at 15 amperes if wired to 120 volts. What is the power requirement of the motor at a power factor of 1?

   Motor power = ____________________________

   or ____________________________

2. The motor power is the same for either voltage. What would the current be if the motor was wired to operate at 240 volts instead of 120?________________

3. The electrician has both voltages available for use, and the motor will work from either. Distance from the power source to the motor is considerable, and the wiring, as well as the switch gear, is yet to be purchased. Which voltage would you recommend? Why?

   a. Recommended voltage– ____________________________

   b. Reasons– ____________________________

   ____

   ____

   ____

AC FUNDAMENTALS
UNIT IV

ASSIGNMENT SHEET #3--CALCULATE THE POWER OF A THREE-PHASE CIRCUIT

NAME______________________________________ SCORE ________________

A three-phase circuit that is properly loaded will have the same amperage in each phase. Voltages between pairs of the three-phases will also be the same. Calculate the power requirement of the three-phase circuit described below.

A three-phase circuit has 20 amperes of current measured in one line, and the voltage is 440.

1. What is the apparent power if the power factor is assumed to be 1?

   a. Watts = ____

   b. Kilowatts = _____________________________________

2. If, according to the equipment operating on it, the circuit does not need that much power, what possible explanations listed below might account for the difference? Check your choices.

   _____ a. Error in measuring amperage

   _____ b. Error in measuring voltage

   _____ c. Power factor less than 1

   _____ d. Equipment not operating properly and requiring more power than normal

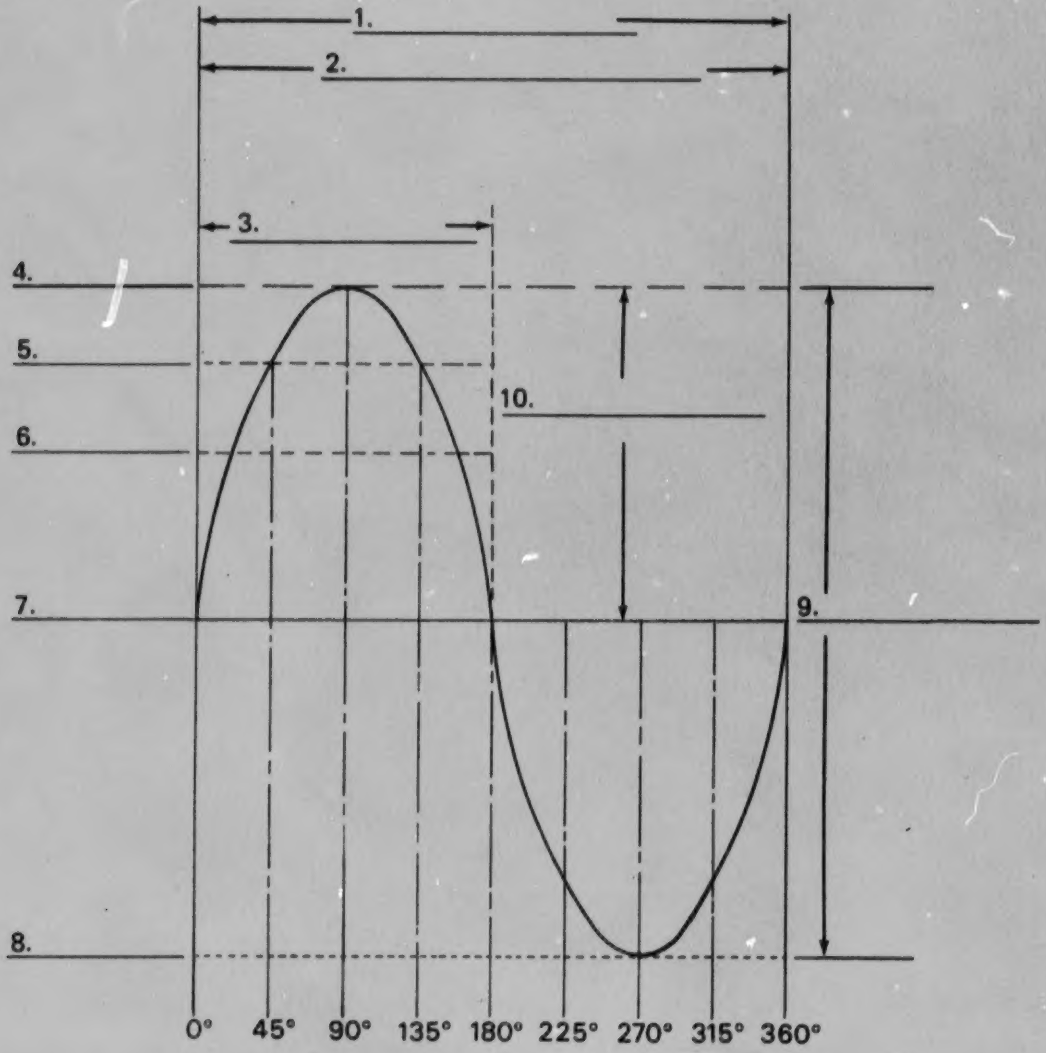
AC FUNDAMENTALS
UNIT IV

ASSIGNMENT SHEET #4--LABEL AC WAVEFORM COMPONENTS

NAME ______________________ SCORE ______________

Label the AC waveform components in Figure 3 below. Write the correct names in the blanks.

FIGURE 3


1. ____
2. ____
3. ____
4. ____
5. ____
6. ____
7. ____
8. ____
9. ____
10. ____
0°
45°
90°
135°
180°
225°
270°
315°
360°

AC FUNDAMENTALS
UNIT IV

ASSIGNMENT SHEET #5--CONVERT FROM ONE VOLTAGE MEASUREMENT TO ANOTHER

NAME__________________________________ SCORE _______________

1. A sine wave measures 60 volts peak-to-peak. What is the peak voltage?

____

2. If the above voltage is to be measured with a multimeter, what voltage will the meter read and what type voltage is it?

Voltage = ____

Type = ____

3. A diagram specifies that a voltage is supposed to be 400 volts.

   a. What type voltage is this?____________________________________

   b. What is the root-mean-square voltage?____________________________

   c. What is the equivalent DC voltage?______________________________

4. In order to measure a 170 volt root-mean-square signal on an oscilloscope, you will measure a Pk-Pk voltage of____________________________.

AC FUNDAMENTALS
UNIT IV

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. 141.4 V
2. 100 W

Assignment Sheet #2

1. 1,800 W or 1.8 kW
2. 7.5 A
3. a. 240 V should be used
   b. Answer may include some of the following
      1. Can use smaller wire because the current is less for the same power; smaller wire costs less
      2. Line loss will be less because $P = I^2 R$ is less when I is less
      3. Voltage drop in the line is less because $E = IR$ is less when I is less
      4. Switch gear could cost less since it will handle less current

Assignment Sheet #3

1. 15,241.6 W or 15.2 kW
2. All of the reasons listed (a, b, c, d) are possible explanations

Assignment Sheet #4

1. Cycle
2. One generator revolution
3. One alternation
4. Positive peak
5. Effective voltage
6. Average voltage

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #4 (continued)

7. O-reference voltage
8. Negative peak
9. Peak-to-peak
10. Peak voltage or zero-to-peak

Assignment Sheet #5

1. 30 V
2. a. 21.21 V
   b. Effective
3. a. Effective
   b. 400 V
   c. 400 V
4. 480.76 Pk-Pk

AC FUNDAMENTALS
UNIT IV

JOB SHEET #1–COMPARE DC VOLTAGE TO AC, ROOT-MEAN-SQUARE VOLTMETER MEASUREMENTS

I. Equipment and materials

- A. Lamps--2, rated at 120 volts, 60 watts or less
- B. Multimeter
- C. DC power supply--Capable of 120 volts at 0.5 amperes
- D. Lamp sockets--2
- E. Power cable with 120 volt plug
- F. Test leads

II. Procedure

A. Measure the AC wall or bench receptacle voltage

(CAUTION: 120 volts can cause injury or death. Do not touch the metal parts of the test leads or lamp sockets.)

B. Record results

AC outlet voltage = ________________________________

Type of voltage = ________________________________

____

C. Use conversion factors to convert the value measured to the peak-to-peak value

D. Record that value

Peak-to-peak value = ________________________________

E. Connect one lamp socket to the 120 volt power cable and plug

F. Insert the lamp, and plug it into the AC outlet

G. Estimate the DC voltage that would be required to make the lamp glow with the same intensity

H. Record the estimate

Equivalent DC estimate = ________________________________

JOB SHEET #1

I. With the DC power supply turned off, connect the other lamp socket

J. Insert the lamp

K. Turn power supply output control to the minimum

L. Turn power supply on, slowly bringing the voltage up until the lamp glows with the same intensity as the AC lamp

(NOTE: Do not exceed 150 volts on the output meter of the power supply.)

M. Measure voltage across the lamp supplied with DC, using the multimeter

N. Record the voltage

Measured DC voltage = ________________________________

O. Turn off power supply

P. Unplug AC power cable

(NOTE: Show your results to the instructor.)

Q. Put equipment and materials away

(CAUTION: Electric light bulbs may still be hot and could cause serious burns.)

AC FUNDAMENTALS
UNIT IV

JOB SHEET #2--MEASURE VOLTAGE AND CURRENT TO A SINGLE-PHASE AC MOTOR

I. Equipment and materials

A. Multimeter--AC ammeter, or clamp-on ammeter with capacity of 5 amperes or a range of not more than 10 amperes full-scale with test leads

B. AC motor–Single-phase, 120 volts (or 120/240 volts), from 1/4 to 1/2 horsepower

C. Motor base, stand, vise, or wood blocking to secure motor from rocking or falling from top of work bench

D. AC voltmeter (unless multimeter listed in A, above, is to be used)--Capable of measuring 120 volts to within 5 volts or less

E. Power cable with 120-volt AC grounded plug

F. Toggle switch--Rated at 120 volts AC or more and 10 amperes or more, mounted in box or on a base

G. Test leads

II. Procedure

A. Measure the value of the AC wall or bench receptacle voltage

(CAUTION: 120 volts AC can cause injury or death. Do not touch the metal parts of the test leads.)

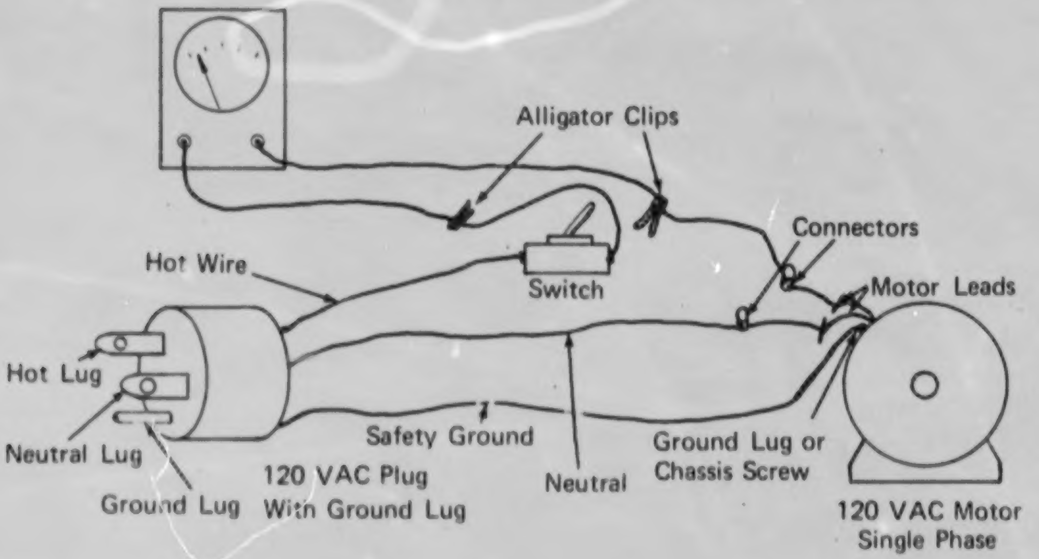
B. Record results

Voltage = ____

JOB SHEET #2

C. Connect motor, power cable, multimeter or ammeter, and toggle switch as indicated in Figure 4

FIGURE 4


Alligator Clips
Connectors
Hot Wire
Switch
Motor Leads
Hot Lug
Neutral Lug
Ground Lug
Safety Ground
120 VAC Plug
With Ground Lug
Neutral
Ground Lug or
Chassis Screw
120 VAC Motor
Single Phase

D. Turn the toggle switch off

E. Set multimeter controls and jacks for amperage measurement of above 5 amperes

F. Secure the motor so that it will not rock due to its starting inertia, pull a connection loose, or fall from the work bench

(NOTE: Have your instructor inspect the circuit, the multimeter settings, the toggle switch position, and the arrangement [illegible] have made to secure the motor.)

G. Plug in the circuit

H. Turn on the toggle switch

I. Record the motor amperage

Motor amperage = ______________________________

J. Open the toggle switch

K. Unplug the circuit

JOB SHEET #2

L. Assuming the power factor is 1, calculate the power to the motor by using the formula, $P = IEP_f$

M. Record the results below

Power = ______________________________

(NOTE: Show your results to the instructor.)

N. Put equipment and materials away

AC FUNDAMENTALS
UNIT IV

JOB SHEET #3--MEASURE VOLTAGE AND CURRENT TO A THREE-PHASE AC MOTOR

I. Equipment and materials

A. Clamp-on ammeter or clamp-on probe for multimeter--Capable of measuring motor current of motor to be used

B. Electric motor--Three-phase, 460 volts or less, prewired for the supply voltage, and connected to a fused disconnect

C. Multimeter with test leads

II. Procedure

A. Remove cover on three-phase motor so power connections are accessible

B. Connect motor to power source

(CAUTION: Contact with the voltages in this circuit can cause serious injury or death. Careless handling of the test leads can result in accidental shorts and arcing which could cause eye injury or skin burns.)

C. Turn on three-phase power

D. Measure current in all motor leads by connecting clamp-on ammeter or probe to each conductor

E. Record measurements

1. Phase A amperes = ______________________________
2. Phase B amperes = ______________________________
3. Phase C amperes = ______________________________

F. Set multimeter selectors for a measurement of 460 volts AC

G. Connect test leads to the proper jacks

(NOTE: Have instructor check your meter settings. Instructor may have you select a lower scale if the circuit is of a lower voltage.)

H. Measure from phase-to-phase (between terminals) in the disconnect box, while being *extremely* careful not to touch metal parts of the test leads

JOB SHEET #3

I. Record voltages

1. Phase A to B = ______________________________
2. Phase B to C = ______________________________
3. Phase A to C = ______________________________

K. Turn off power to motor

K. Use the formula P = IE x 1.732 to calculate the power to motor

L. Record the power

Power calculated = ______________________________

(NOTE: Show your results to the instructor.)

M. Put equipment and materials away

AC FUNDAMENTALS
UNIT IV

JOB SHEET #4--MEASURE AC VOLTAGE AND FREQUENCY

I. Equipment and materials

   A. Function generator

   B. Frequency counter

   C. Multimeter

   D. Test leads

II. Procedure

   A. Set up test equipment

   B. Review operating procedures for the frequency counter

   (NOTE: Have the instructor pre-set the output of the function generator.)

   C. Measure voltage and frequency and record below

   Frequency = ______________________________

   Voltage = ______________________________

   D. Repeat step D for each position of the function selector

   E. Record results

   Frequency = ____________ Voltage = ________________

   Frequency = ____________ Voltage = ________________

   F. Did the amplitude and frequency change? __________

   Explain ______________________________

   ____

   ____

   ____

   ____

JOB SHEET #4

G. Repeat steps D through G

(NOTE: Before repeating steps, have the instructor change the function generator setting.)

Frequency = ____________________ Voltage = ________________

Frequency = ____________________ Voltage = ________________

Frequency = ____________________ Voltage = ________________

Explain ____

____

____

____

____

(NOTE: Discuss your results with instructor.)

H. Turn off test equipment

I. Put equipment and materials away

AC FUNDAMENTALS
UNIT IV

TEST

NAME____ SCORE __________________

1. Match terms associated with AC fundamentals to their correct definitions. Write the correct numbers in the blanks.

_____a. Voltage that continuously varies in magnitude and periodically reverses direction

_____b. Direction of electrical current flow; potential or tendency to flow; magnetic direction

_____c. Mathematical term for AC or voltage expressed as a value that compares to DC or voltage effectiveness

_____d. Average of the waveform amperage or voltage which is not equal to the peak value or root-mean-square value

_____e. Cycles per second

_____f. Frequency; interpretation for the term *hertz*; rate at which basic waveform is repeated

_____g. Relating to a point in the cycle of one AC waveform compared to another AC waveform or compared to time; an AC source or conductor

_____h. Distance an AC waveform travels during the time of one cycle

_____i. Assembly of a generator which supplies the output; may be rotating or stationary, or assembly of an electric motor that is forced to move; center or outside assembly may rotate

_____j. Coils and magnets that supply the magnetic field for a generator or motor armature; may rotate or be stationary; any area where magnetic force is concentrated

_____k. One end of a magnet; a section of a generator or motor that produces magnetism or electrical current

1. Average value
2. Wave length
3. Hertz
4. Root-mean-square
5. Alternating current
6. Armature
7. Phase
8. Cycles per second
9. Polarity
10. Pole
11. Field

TEST

_____l. Divided ring on a motor or generator rotor that acts as a rotating switch that selects and exchanges current between the rotor poles and outside circuits

_____m. Mathematical figure that represents a measure of how well voltage and amperage are working in unison

_____n. DC generator or DC power source that provides power to the field magnets of a generator

_____o. One thousand watts

_____p. One half of a cycle, either positive or negative

_____q. Change of an alternating waveform from zero to a negative peak, back through zero to a positive peak, and back to zero

_____r. Instrument the produces an image of voltage on a cathode-ray tube screen

_____s. Instrument in which frequency can be measured directly without coversion through the use of digital display

_____t. Peak height of the AC sine wave; measured in volts

12. Commutator
13. Kilowatt
14. Oscilloscope
15. Cycle
16. Alternation
17. Frequency counter
18. Exciter
19. Power factor
20. Amplitude

2. Match abbreviations associated with AC fundamentals to their correct definitions. Write the correct numbers in the blanks.

_____a. Alternating current

_____b. Direct current

_____c. Root-mean-square

_____d. Hertz

_____e. Cycles per second

_____f. Phase

_____g. Cycle

_____h. Frequency

_____i. Volt

_____j. Revolutions per minute

1. Cyc
2. cps
3. DC
4. V
5. rpm
6. Freq
7. Ph
8. Hz
9. rms
10. AC

TEST

_____k. North magnetic pole

_____l. South magnetic pole

_____m. Power factor

_____n. Kilowatt

_____o. Peak

_____p. Peak-to-peak

_____q. Effective

_____r. Average

11. Pk
12. Ave
13. S
14. P_f
15. N
16. Eff
17. kW
18. Pk-Pk

3. Identify symbols associated with AC. Write the correct answers in the blanks.

Alternating waveform, AC

Phase

Negative polarity indicator

Positive polarity indicator

Wave length

–

a. ______________________________

λ

b. ______________________________

ϕ

c. ______________________________

+

d. ______________________________

~

e. ______________________________

TEST

4. Distinguish between advantages and disadvantages of AC compared to DC. Write an "A" in the blanks before advantages and a "D" in the blanks before disadvantages.

_____a. Require DC in many industrial applications

_____b. Can be used to drive synchronous motors

_____c. Are less expensive in large motors than in equivalent other current motors

_____d. Must be stored indirectly

_____e. Does not always work with voltage for best efficiency

_____f. Is simple, economical to produce

_____g. Must operate variable speed motors indirectly

_____h. May hum and vibrate at low frequencies

_____i. Can be readily transformed to higher or lower voltages

_____j. Can radiate high frequency over distances without conductors

5. In the space provided, describe the left-hand rule for generating current.

____

____

____

____

____

____

6. In the space provided, state how electricity is generated.

____

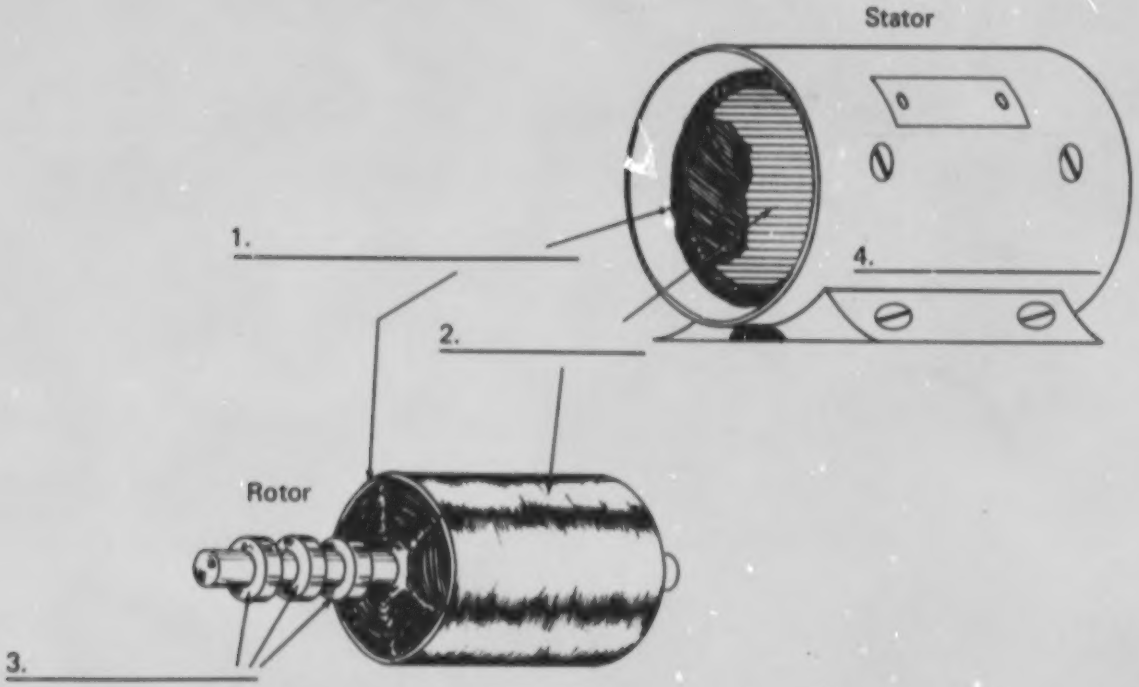
____

____

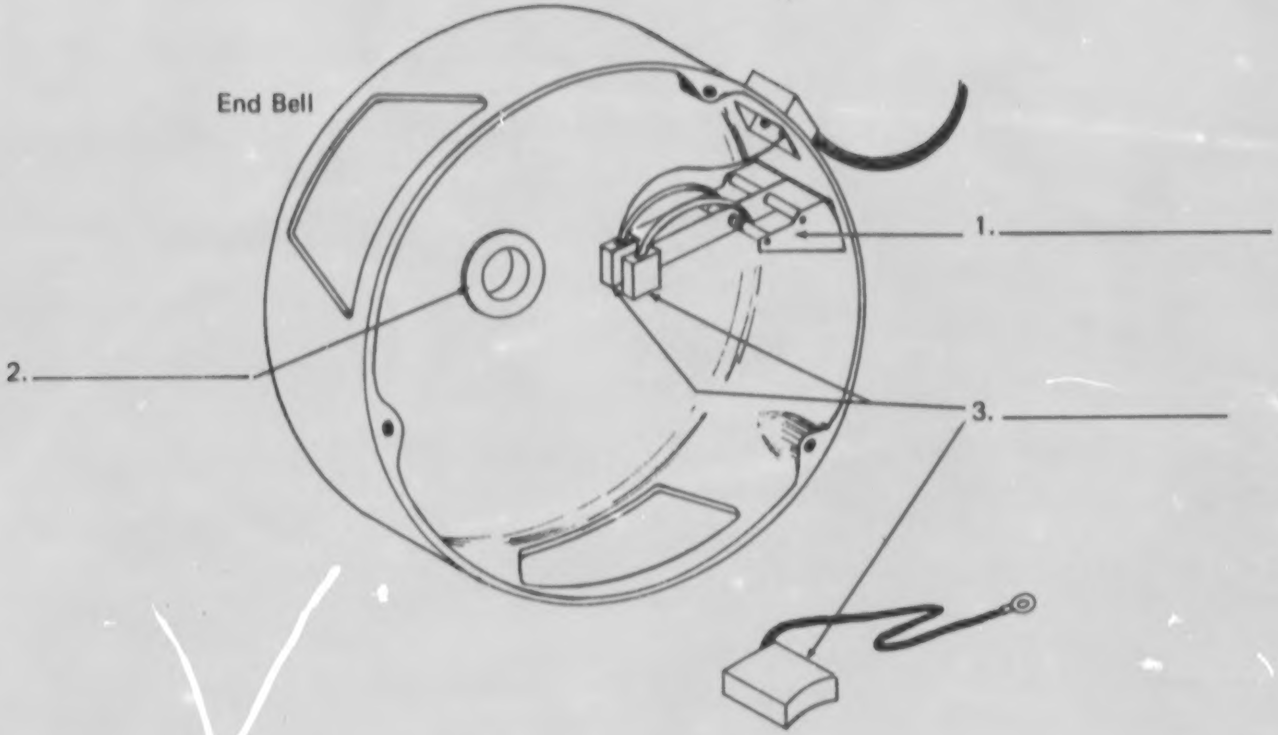
____

TEST

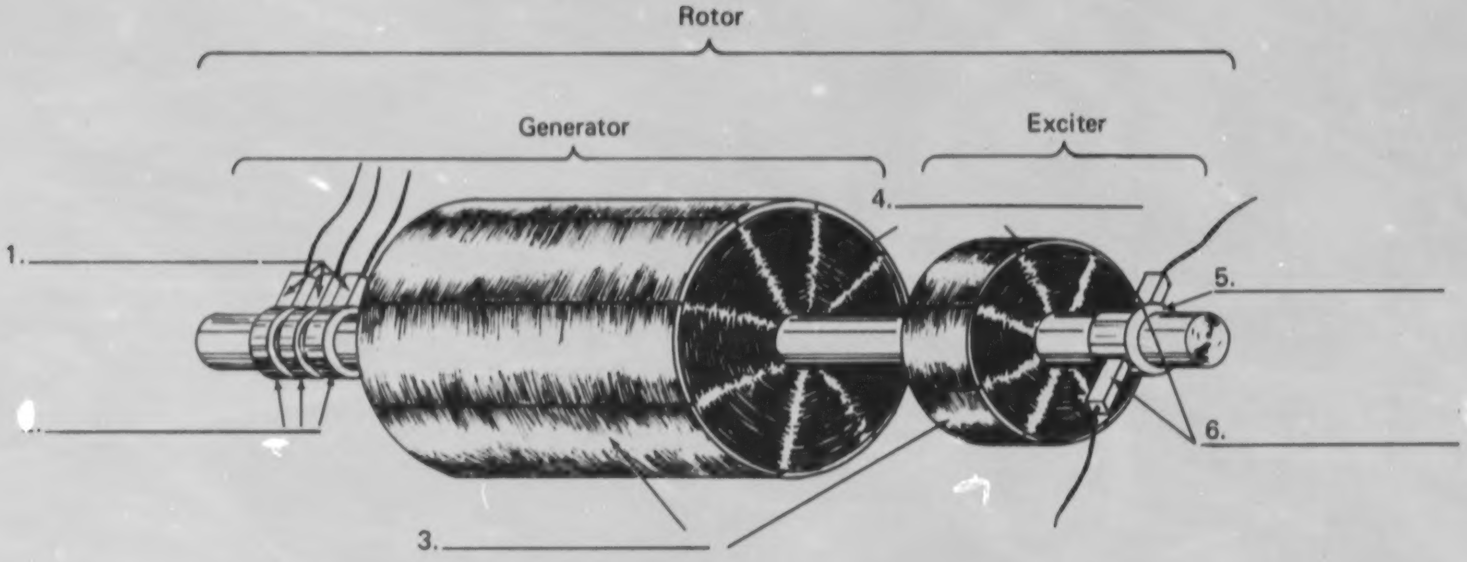
7. Label the principal parts of a generator in the following illustrations. Write the correct answers in the blanks provided.


Stator
1. ______
4. ______
2. ______
Rotor
3. ______

TEST


End Bell
1. ____
2. ____
3. ____

TEST
Rotor


Rotor
Generator
Exciter
1.
4.
5.
6.
3.

TEST

8. State factors that determine frequency of generated AC.

a. ______________________________

b. ______________________________

9. Name methods of measuring frequency.

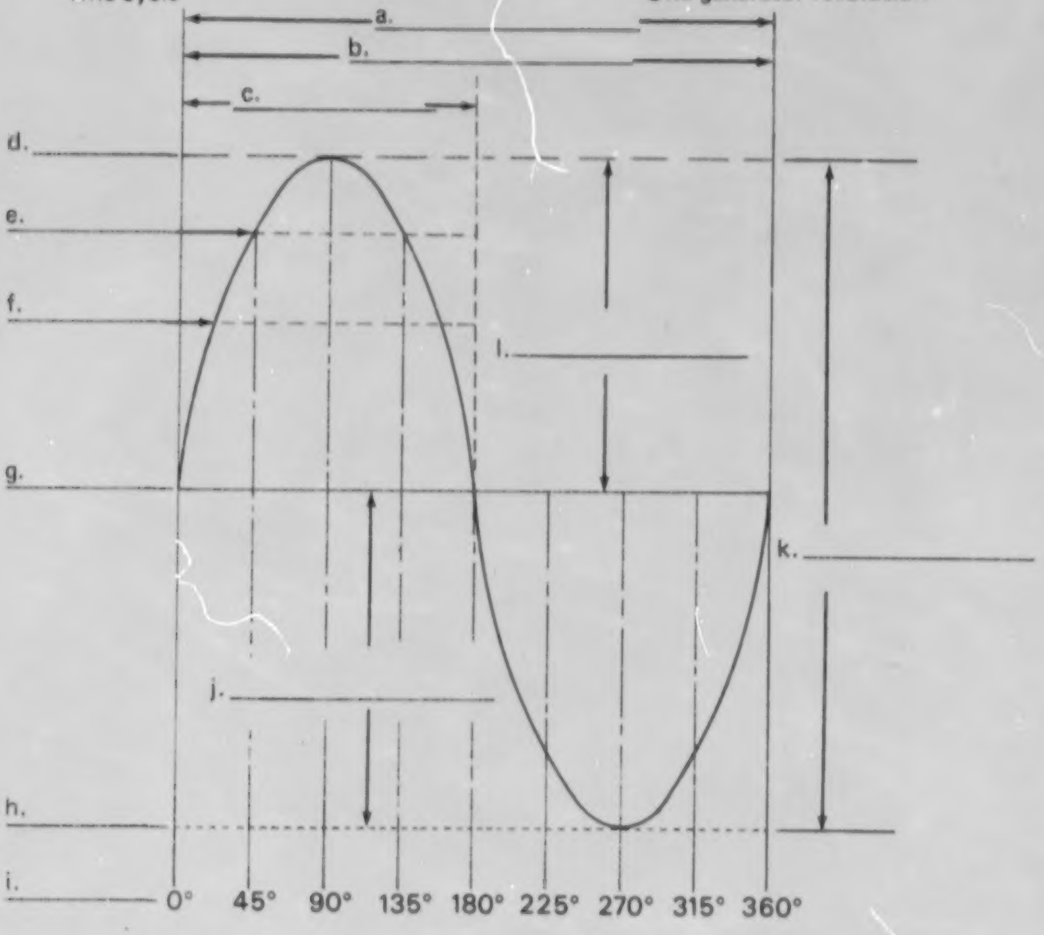
a. ______________________________

b. ______________________________

10. Identify AC waveform components. Write your answers in the blanks provided.

Peak-to-peak
Zero-to-peak (negative)
Zero-to-peak (positive)
Average
One alternation
One cycle

Negative peak
Generator rotor position
Zero line reference
Root-mean-square
Positive peak
One generator revolution



TEST

11. Name methods of producing AC for shop use.

    a. ______________________________

    b. ______________________________

12. Solve problems converting from one AC measurement to another AC measurement.

    a. A technician has measured an AC signal on the oscilloscope as 200 volts peak-to-peak. What is the effective voltage of that signal? ______________

    b. An electronic component is rated as being capable of operating at alternating voltages that average 30 volts. What peak-to-peak voltage is this equal to? ______________

    c. Positive alternations of an AC power source are found to be 150 volts in amplitude from zero-to-peak. What is the rms value of the original AC power source? ______________

    d. An ammeter measures 10 amperes rms in a motor circuit. What is the zero-to-peak value of the current? ______________

13. Define three-phase power.

    ____

    ____

    ____

    ____

TEST

14. State the real power formulas for AC single-phase and three-phase circuits.

    a. Single-phase-- ______________________________

    b. Three-phase-- ______________________________

(NOTE: Test questions 15-19 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

15. Convert an DC voltage to an equivalent AC voltage.

16. Calculate the power to an AC motor.

17. Calculate the power of a three-phase circuit.

18. Convert from one voltage measurement to another.

19. Demonstrate the ability to

    a. Compare DC voltage to AC, root-mean-square voltmeter measurements.

    b. Measure voltage and current to a single-phase AC motor.

    c. Measure voltage and current to a three-phase AC motor.

    d. Measure AC voltage and frequency.

AC FUNDAMENTALS
UNIT III

ANSWERS TO TEST

1.

a.	5	k.	10
b.	9	l.	12
c.	4	m.	19
d.	1	n.	18
e.	3	o.	13
f.	8	p.	16
g.	7	q.	15
h.	2	r.	14
i.	6	s.	17
j.	11	t.	20

2.

a.	10	j.	5
b.	3	k.	15
c.	9	l.	13
d.	8	m.	14
e.	2	n.	17
f.	7	o.	11
g.	1	p.	18
h.	6	q.	16
i.	4	r.	12

3. a. Negative polarity indicator
   b. Wave length
   c. Phase
   d. Positive polarity indicator
   e. Alternating waveform; AC

ANSWERS TO TEST

4. a. D f. A

   b. A g. D

   c. A h. D

   d. D i. A

   e. D j. A

5. Description should include:

   Make thumb, index finger, and middle finger of the left hand all point at right angles to each other. If the motions of the conductors are indicated by the thumb, and the direction of the magnetic field is indicated by the index finger, then the middle finger will point in the direction of electron current flow

6. Electricity is generated when motion occurs at right angles between conductors of a complete circuit and a magnetic field

7. a.
   1. Windings
   2. Poles
   3. Slip rings
   4. Frame

   b.
   1. Brush rigging
   2. Bearing
   3. Brushes

   c.
   1. Brushes
   2. Slip rings
   3. Poles
   4. Windings
   5. Commutator
   6. Brushes

8. a. Number of magnetic field and armature poles

   b. Speed of rotation

9. a. Using an oscilloscope

   b. Using a frequency counter

ANSWERS TO TEST

10. a. One cycle
    - b. One generator revolution
    - c. One alternation
    - d. Positive peak
    - e. Root-mean-square
    - f. Average
    - g. Zero line reference
    - h. Negative peak
    - i. Generator rotor position
    - j. Zero-to-peak (negative)
    - k. Peak-to-peak
    - l. Zero-to-peak (positive)
11. a. Use an AC power supply
    - b. Use a function generator
12. a. 70.7 V
    - b. 94.3V Pk-Pk
    - c. 106.05 V
    - d. 14.14 Zero-to-Peak
13. Three AC waveforms from a common source, each peaking 120° apart, and each conducted on a separate line
14. a. $P = IE\,P_f$
    - b. $P = IE\sqrt{3}\,P_f$
15. Evaluated to satisfaction of instructor
16. Evaluated to satisfaction of instructor
17. Evaluated to satisfaction of instructor
18. Evaluated to satisfaction of instructor
19. Performance skills evaluated to satisfaction of instructor

METERS
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to measure voltage, current, and resistance using both the permanent magnet moving coil meter and the digital multimeter. The student should also be able to increase the range of both the ampmeter and the voltmeter. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with multimeters to their correct definitions.
2. Name the two common types of multimeters.
3. Match symbols and abbreviations associated with multimeters to their correct interpretations.
4. List general steps used in preparing a multimeter for operation.
5. Arrange in order procedures for measuring voltage.
6. Arrange in order procedures for measuring amperage.
7. Arrange in order procedures for measuring resistance.
8. Distinguish between characteristics of ammeters amd voltmeters.
9. Match amperage measurement techniques to their correct descriptions.
10. Match voltage measurement techniques to their correct descriptions.
11. Compute ammeter shunt resistance.
12. Compute voltmeter series resistance.
13. Determine ammeter loading effects.
14. Determine voltmeter loading effects.
15. Determine the current of a multiple-loop, clamp-on ammeter application.
16. Determine circuit characteristics through indirect means.
17. Determine variables and values from multimeter control settings and dial indications.

OBJECTIVE SHEET

18. Set multimeter controls for measurements.

19. Demonstrate the ability to

    a. Measure direct current voltage sources using a multimeter.

    b. Measure direct current circuit voltages using a multimeter.

    c. Measure direct current amperes in a circuit using a multimeter.

    d. Measure alternating current voltages using a multimeter.

    e. Measure three-phase alternating current power using a multimeter.

    f. Measure alternating current using a multimeter.

    g. Measure resistance using a multimeter.

METERS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheets.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Demonstrate types of equipment shown in transparency drawings and referred to in assignment sheets.

   H. Have students re-do all job sheets using a different type of meter, if available.

   I. Give test.

II. Instructional materials

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM #1--Permanent Magnet Moving Coil Multimeter

      2. TM #2--Digital Multimeter

      3. TM #3--Correct Voltage Measurements

      4. TM #4--Correct Amperage Measurements

      5. TM #5--Correct Resistance Measurements

      6. TM #6--Amperage Measurement Techniques

      7. TM #7--Amperage Measurement Techniques (Continued)

      8. TM #8--Voltage Measurement Techniques

      9. TM #9--Voltage Measurement Techniques (Continued)

SUGGESTED ACTIVITIES

D. Assignment sheets

  1. Assignment Sheet #1--Compute Ammeter Shunt Resistance
  2. Assignment Sheet #2--Compute Voltmeter Series Resistance
  3. Assignment Sheet #3--Determine Ammeter Loading Effects
  4. Assignment Sheet #4--Determine Voltmeter Loading Effects
  5. Assignment Sheet #5–Determine the Current of a Multiple-Loop, Clamp-on Ammeter Application
  6. Assignment Sheet #6--Determine Circuit Characteristics Through Indirect Means
  7. Assignment Sheet #7--Determine Variables and Values From Multimeter Control Settings and Dial Indications
  8. Assignment Sheet #8--Set Multimeter Controls for Measurements

E. Answers to assignment sheets

F. Job sheets

  1. Job Sheet #1--Measure Direct Current Voltage Sources using a Multimeter
  2. Job Sheet #2--Measure Direct Current Circuit Voltages using a Multimeter
  3. Job Sheet #3--Measure Direct Current Amperes in a Circuit using a Multimeter
  4. Job Sheet #4--Measure Alternating Current Voltages using a Multimeter
  5. Job Sheet #5--Measure Three-Phase, Alternating Current Power using a Multimeter
  6. Job Sheet #6–Measure Alternate Current using a Multimeter
  7. Job Sheet #7–Measure Resistance using a Multimeter

G. Test

H. Answers to test

SUGGESTED ACTIVITIES

III. Unit references

A. Beach, David. *Electronics Instructional System: DC Electronics, AC Electronics, Semiconductor Devices/Applications.* Unit III: "Multimeters." Columbia, Missouri: University of Missouri, n.d.

B. Cooper, William David. *Electronic Instrumentation and Measurement Techniques.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1970.

C. Gebert, Kenneth L. and Kenneth R. Edwards. *Transformers.* 2nd ed., Chicago: American Technical Society, 1974.

METERS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Accuracy--How near the instrument reading is to the actual value

B. Precision–Instrument consistency

EXAMPLE: A "precision meter" might not be accurate. It may measure 1 volt at 1.20 volts, but each time the reading will be precisely 1.20, not 1.21 or 1.19. A calibration adjustment could correct the meter reading to 1.00 at 1 volt and would then precisely repeat a 1.00 reading.

C. Sensitivity--How well an instrument responds to small measurements or small changes in the value being measured

D. Resolution–How well the instrument will indicate a small change in the measured value

EXAMPLE: A precise, accurate, and sensitive meter may respond by moving the meter hand 1/16" for a small change in measured amperage. If the scale is marked only one division per inch, the meter would still lack "resolution" since the operation could not determine what amount of current change this represents.

E. Error--How far the measurement is from the actual value

F. Calibration–Technique of testing and adjusting an instrument by referencing it to another instrument or device of known accuracy and precision

G. Multimeter--Instrument capable of measuring a "multiple" of values

EXAMPLES: Amperage, voltage, and resistance with several measurement ranges

H. Branch circuit–Circuit originating from a main circuit, often one of many; one of several parallel circuits

I. Shunt--Circuit that bypasses another circuit or device, especially a low-resistance bypass for an ammeter circuit

J. Internal resistance--Total resistance offered by a device

K. Ground--Electrical point or any good conductor that is connected to a common chassis with zero relative voltage; usually conductors are connected to the earth

INFORMATION SHEET

L. Voltage--Electromotive force (emf); force that drives electrictiy through conductors; must be measured across, between, or be referenced to a second point

EXAMPLE: Ground

M. Amperage--Electricity; electrical current flow; electron flow; must be measured at a point within a circuit

N. Resistance--Opposition to electrical current flow; impedance; measured in units of ohms; must be measured from one point to another

II. Common types of multimeters

A. Permanent magnet moving coil (Transparency #1)

B. Digital (Transparency #2)

III. Symbols and abbreviations and their interpretations

A. **VOM**--Voltohmmeter

B. **DMM**--Digital multimeter

C. **VTVM**--Vacuum tube voltmeter

D. **Ω**--Ohm

E. **V**--Volt

F. **A**--Amp

G. **m**--milli

H. **K**--Kilo

I. **M**--Mega

J. **μ**--Micro

K. **AC**--Alternating current

L. **DC**--Direct current

M. **R**--Resistance

N. **R x 100**--Resistance times one hundred

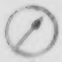
(NOTE: Resistance is actually the resistance reading.)

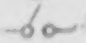
O. **LED**--Light emitting diode

P. **DB**--Decibel

Q. -/\/\/- --Resistor

INFORMATION SHEET

R.  --Meter

S.  Switch

IV. General steps used in preparing a multimeter for operation (Transparencies #1 and #2)

A. Select function to be measured

EXAMPLES: Volts, amps, milliamps, ohms, megohms

B. Select the range or anticipated limits of measurement required

EXAMPLES: 500 A; 200 mA; 1,000 V; R × 100

(NOTE: Some multimeter range switches also select certain functions. [Transparency #1].)

C. Connect test leads to proper test jacks

EXAMPLES: Common and (+), common and V-Ω, common and 10 A

D. Make necessary meter adjustments

EXAMPLES: Set "Ohms Zero Adjust" for a zero ohms reading with meter prepared for ohms measurement and leads connected

(NOTE: "Meter zero" and "zero ohms" readings are at opposite ends of the scale.)

V. Procedures for measuring voltage (Transparency #3)

A. Position meter to correct function

EXAMPLES: -DC, +DC, or AC

B. Observing polarity, connect meter leads to meter

C. Determine correct range scale

(NOTE: Use highest range if voltage is unknown.)

D. Observing polarity, connect meter leads to circuit to be tested

(NOTE: Always hook voltmeter across the component or power source to be tested. Turn off power when installing meter leads whenever possible.)

E. Set meter on lowest scale at which it will register

F. Read correct voltage

G. Disconnect meter leads

H. Turn off meter

INFORMATION SHEET

VI. Procedures for measuring amperage (Transparency #4)

A. Turn off power to circuit under test

B. Position meter to correct scale

C. Determine correct range

(NOTE: Use highest scale if amperage is unknown.)

D. Observing polarity, connect test leads to meter

E. Hook meter in circuit to be tested, observing polarity and connecting in series with the circuit

F. Turn on equipment under test

G. Observe meter reading

H. Postion range switch to correct scale for most accurate reading

I. Determine correct amperage reading

J. Turn off power to equipment

K. Disconnect meter

L. Reconnect circuit

M. Turn off meter

VII. Procedures for measuring resistance (Transparency #5)

A. Turn off power to circuit under test

B. Position meter to the correct function position

C. Position meter range switch to one of the resistance scales

D. Insert meter leads in correct meter jacks, observing polarity

E. Isolate component to be checked

EXAMPLE: Unhook one end of component.

F. Connect meter across component to be measured

G. Determine correct meter position closest to center scale or toward zero

H. Remove leads from component and touch (short) leads together while using "Ohms Zero Adjust" to position meter to the zero position

INFORMATION SHEET

- I. Reconnect meter to component
- J. Read meter for ohmic value
- K. Remove meter leads
- L. Turn off meter
- M. Reconnect component in circuit

VIII. Characteristics of meters

- A. Voltmeter
  - 1. High impedance to current flow
  - 2. Range can be increased by adding a series resistance
  - 3. Measures across the circuit or device
- B. Ammeter
  - 1. Low impedance to current flow
  - 2. Range can be increased by adding a parallel (shunt) resistance
  - 3. Measures in series with the circuit or device

IX. Amperage measurement techniques (Transparencies #6 and #7)

- A. Directly in series--All current passes through the ammeter; technique limited to small measurements; alternating current or direct current can be measured
- B. Clamp-on probe--Gauging amperage by strength of the magnetic field around the conductor; technique limited to moderate alternating current voltages and moderate current values
- C. Current transformer–Measurement equipment isolated from main conductor; technique used for high voltage and high alternating current applications

X. Voltage measurement techniques (Transparencies #8 and #9)

- A. Direct parallel measurement--Voltmeter probes connect directly across terminals; limited to moderate AC or DC voltages
- B. High voltage probe--Voltmeter connects through a high resistance device which limits current and drops the voltage; limited to high AC or DC voltages
- C. Potential transformer--Voltmeter connects to a device that isolates the voltmeter from the primary source and produces only a fraction of the voltage to be measured; used in measuring very high AC voltages, usually in electrical substations

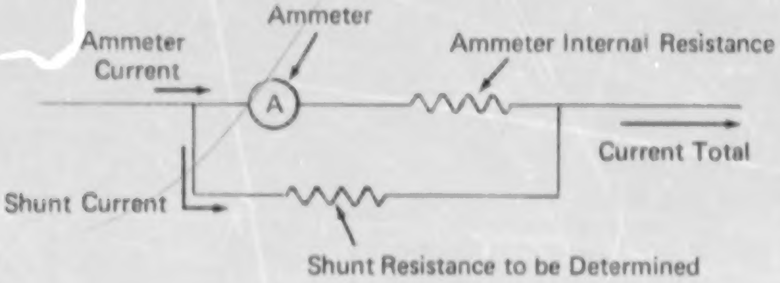
INFORMATION SHEET

XI. Computing ammeter shunt resistance

A. Sketch the meter and shunt circuit (Figure 1)

EXAMPLE:

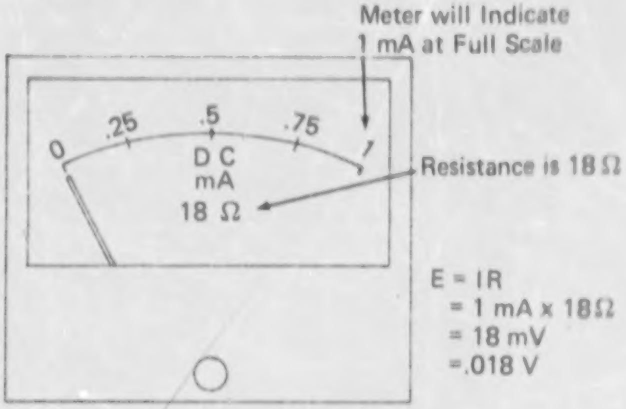
FIGURE 1


Ammeter
Ammeter Current
Ammeter Internal Resistance
A
Current Total
Shunt Current
Shunt Resistance to be Determined

B. Multiply the meter full-scale current by the meter resistance (E =IR) to get the voltage across the meter at full-scale (Figure 2)

EXAMPLE:

FIGURE 2


Meter will Indicate 1 mA at Full Scale
0
.25
.5
.75
1
D C
mA
18 Ω
Resistance is 18 Ω

$$E = IR$$
$$= 1\ \text{mA} \times 18\Omega$$
$$= 18\ \text{mV}$$
$$= .018\ \text{V}$$

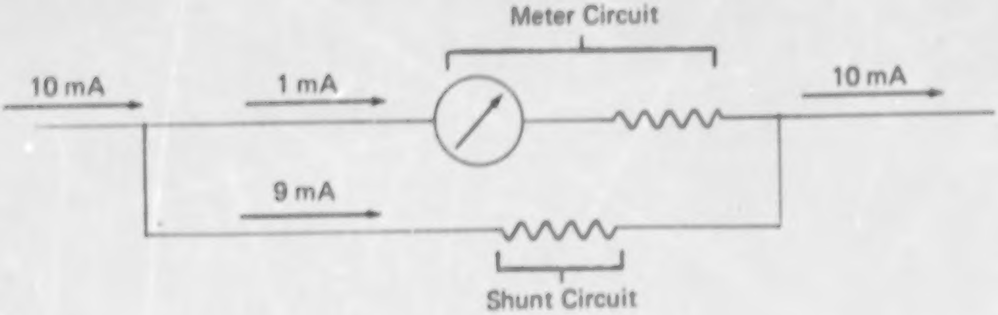
(NOTE: If the meter resistance is not listed on the meter face, check with the supplier or refer to equipment catalogs. An approximation can be made by measuring the voltage across the meter with current passing through it. Divide the voltage measurement by the meter current to get the approximate meter resistance.)

INFORMATION SHEET

C. Subtract the meter current from the total current to be measured to get the current of the shunt (Figure 3)

EXAMPLE: The meter must indicate full-scale when the line has 10 milliamperes. The meter full-scale current is 1 milliampere.

FIGURE 3



D. Divide the meter voltage by the shunt current ($R = \frac{E}{I}$) to get the necessary shunt resistance

EXAMPLE: $R = \frac{E}{I}$

$= \frac{18\text{ mV}}{9\text{ mA}}$

$= 2$ ohms

(NOTE: The milli multiplier cancelled out of both the numerator and denominator of the division above. Decimal equivalents are shown below.)

$R = \frac{.018\text{ v}}{.009\text{ A}}$

$= \frac{18\text{ V}}{9\text{ A}}$

$= 2$ ohms

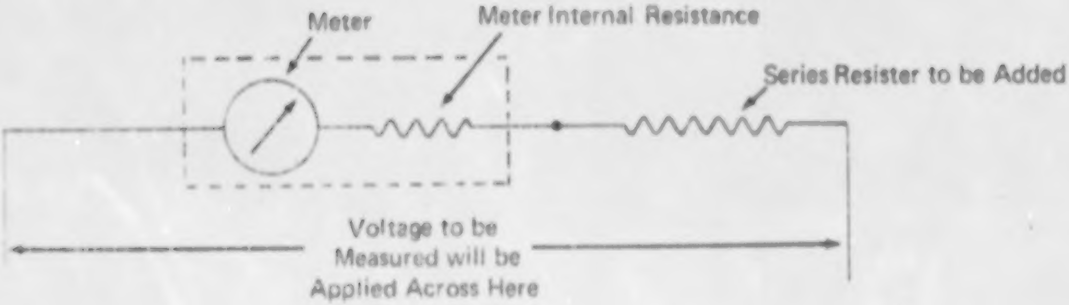
INFORMATION SHEET

XII. Computing voltmeter series resistance

A. Sketch the meter and series resistance (Figure 4)

EXAMPLE:

FIGURE 4


Meter
Meter Internal Resistance
Series Resister to be Added
Voltage to be Measured will be Applied Across Here

B. Divide the meter full-scale voltage by the meter internal resistance to get the meter full-scale current

(NOTE: This procedure will show that a voltmeter is actually an ammeter with a scale marked in volts at points where those voltage values correspond to the amperage values, which actually account for the meter movement.)

EXAMPLE: Meter full-scale = 10 volts

Meter resistance = 2,000 ohms

$$I = \frac{E}{R}$$

$$= \frac{10 \text{ volts}}{2,000 \text{ ohms}}$$

= .005 amperes or (5 milliamperes)

INFORMATION SHEET

C. Find the total resistance of the higher voltage circuit by dividing the new full-scale voltage by the meter full-scale current obtained in Step B

EXAMPLE: To change this meter so that a full-scale indication represents 100 volts

$$R\ (\text{total}) = \frac{E}{I}$$

$$= \frac{100\ \text{volts}}{.005\ \text{amperes}}$$

$$= 20{,}000\ \text{ohms, or } 20\text{K}$$

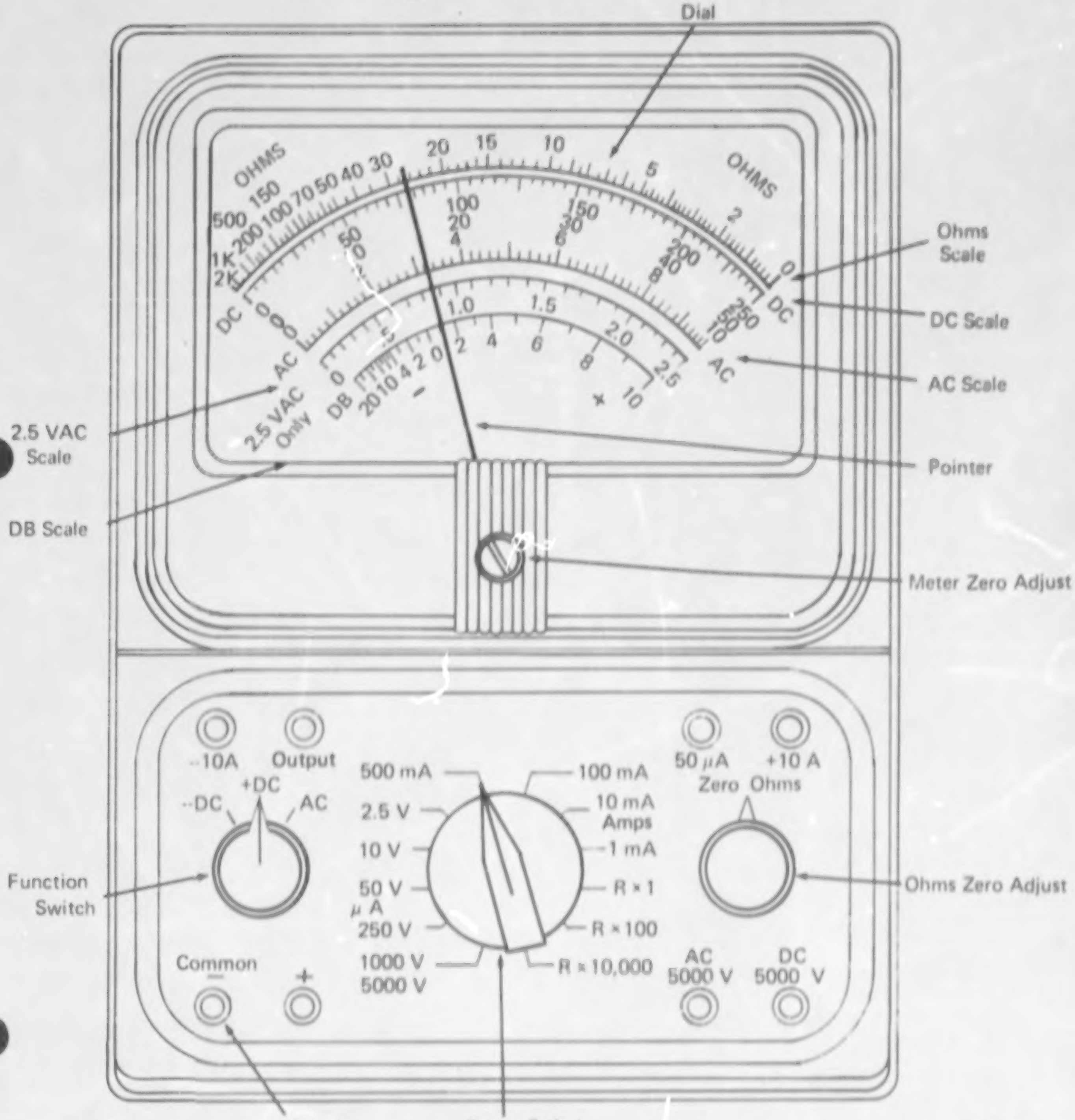
D. Subtract the meter resistance from the total resistance to get the required series resistor

EXAMPLE: $R\ (\text{series}) = R\ (\text{total}) - R\ (\text{meter})$

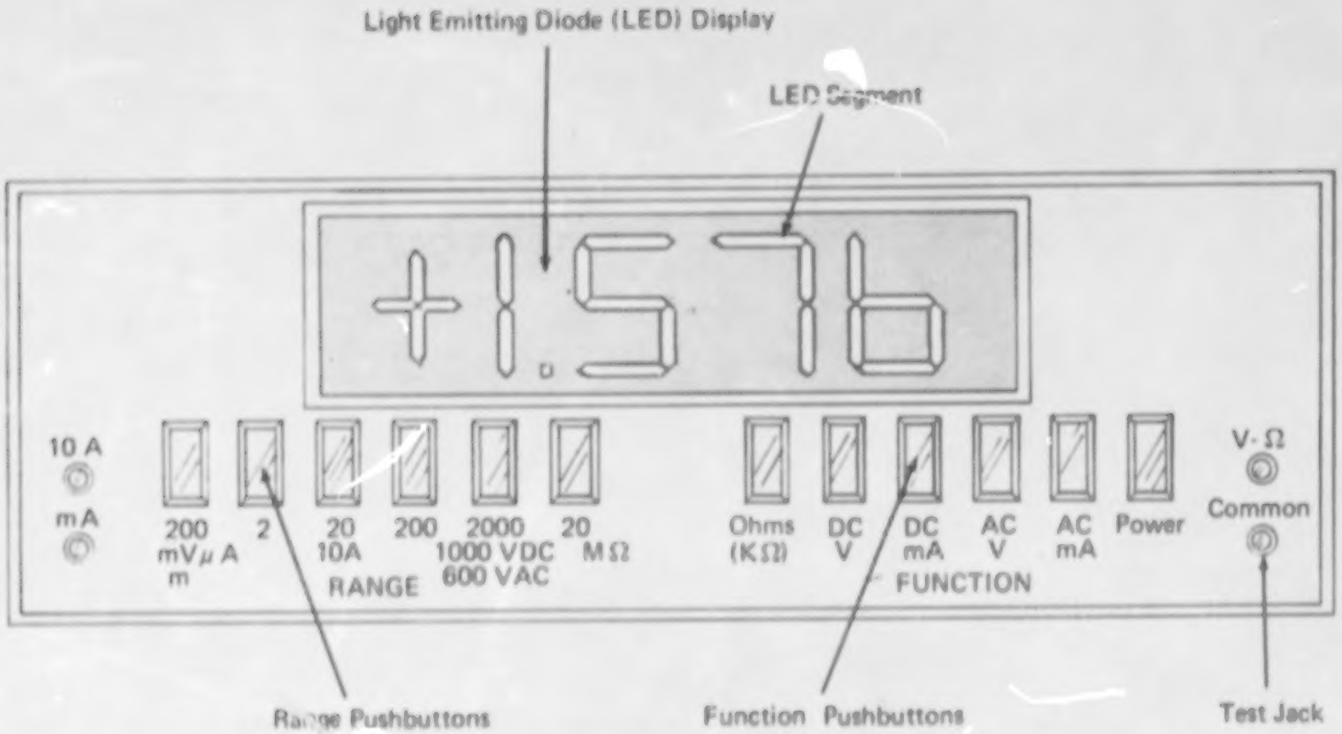
$$= 20{,}000 - 2{,}000$$

$$= 18{,}000\ \text{ohms, or } 18\text{K ohms}$$

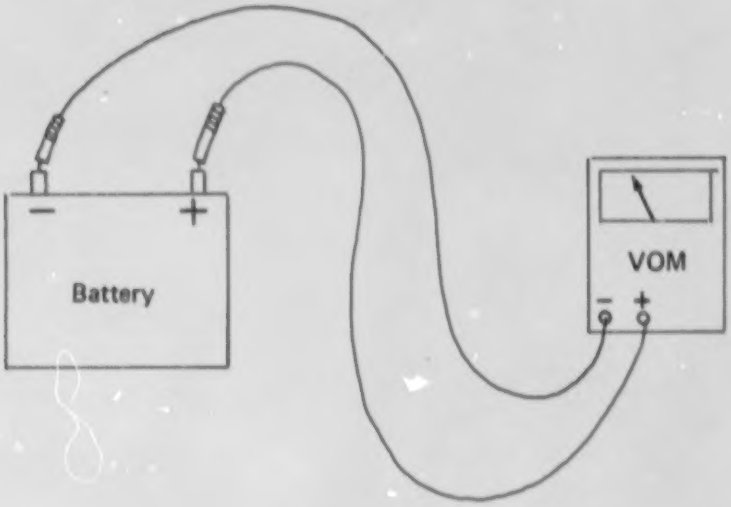
Permanent Magnet Moving Coil Multimeter

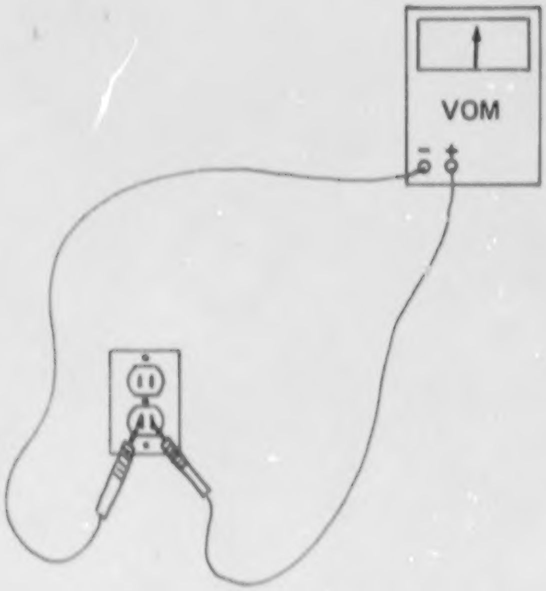

Dial
OHMS
500
150
200
100
70
50
40
30
20
15
10
5
OHMS
2
1K
2K
0
DC
AC
2.5 VAC Only
DB
1.0
1.5
2.0
2.5
10
8
6
4
2
0
20
+
-
Ohms Scale
DC Scale
AC Scale
2.5 VAC Scale
DB Scale
Pointer
Meter Zero Adjust
-10A
Output
50 μA
+10 A
Zero Ohms
-DC
+DC
AC
500 mA
2.5 V
10 V
50 V
μA
250 V
1000 V
5000 V
100 mA
10 mA
Amps
1 mA
R × 1
R × 100
R × 10,000
AC 5000 V
DC 5000 V
Common
-
+
Function Switch
Ohms Zero Adjust
Test Jack
Range Switch

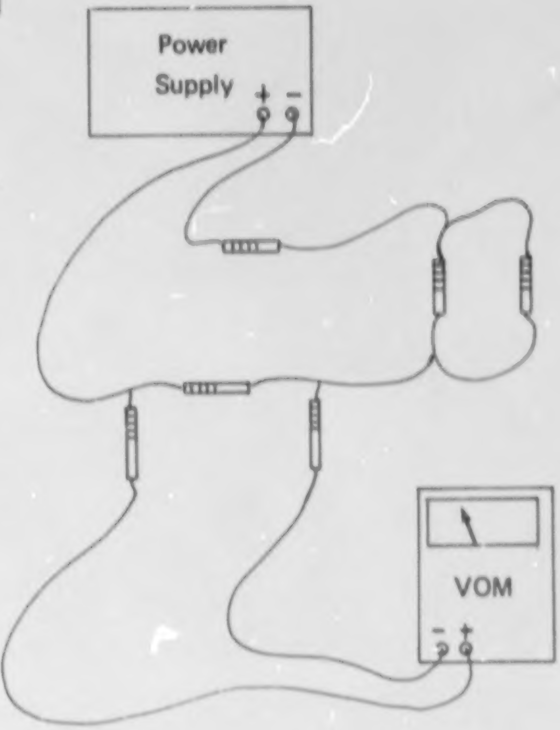
Digital Multimeter


Light Emitting Diode (LED) Display
LED Segment
+1.576
10 A
mA
200 mV µA m
2
20 10A
200
2000 1000 VDC 600 VAC
20 MΩ
RANGE
Ohms (KΩ)
DC V
DC mA
AC V
AC mA
Power
FUNCTION
V·Ω
Common
Range Pushbuttons
Function Pushbuttons
Test Jack

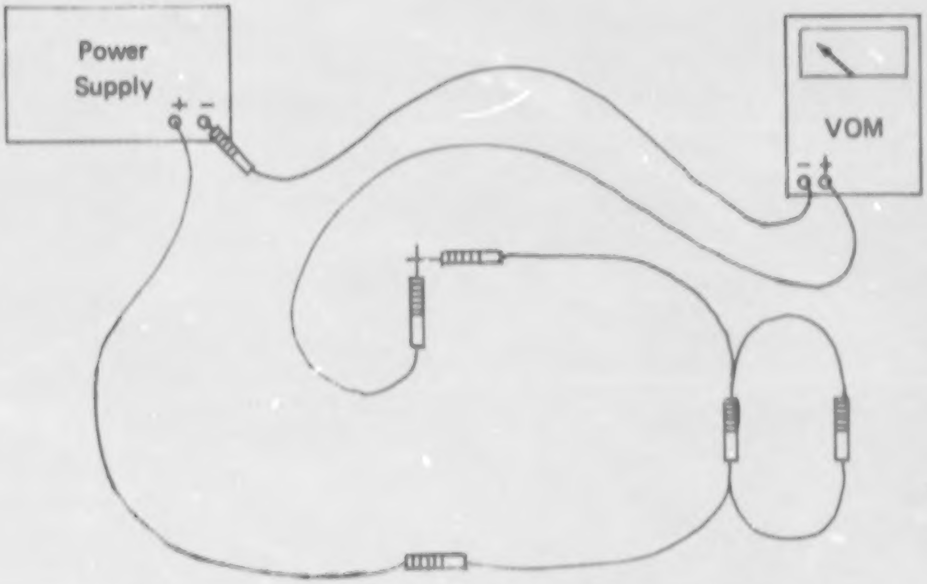
Correct Voltage Measurements


−
+
Battery
VOM
− +

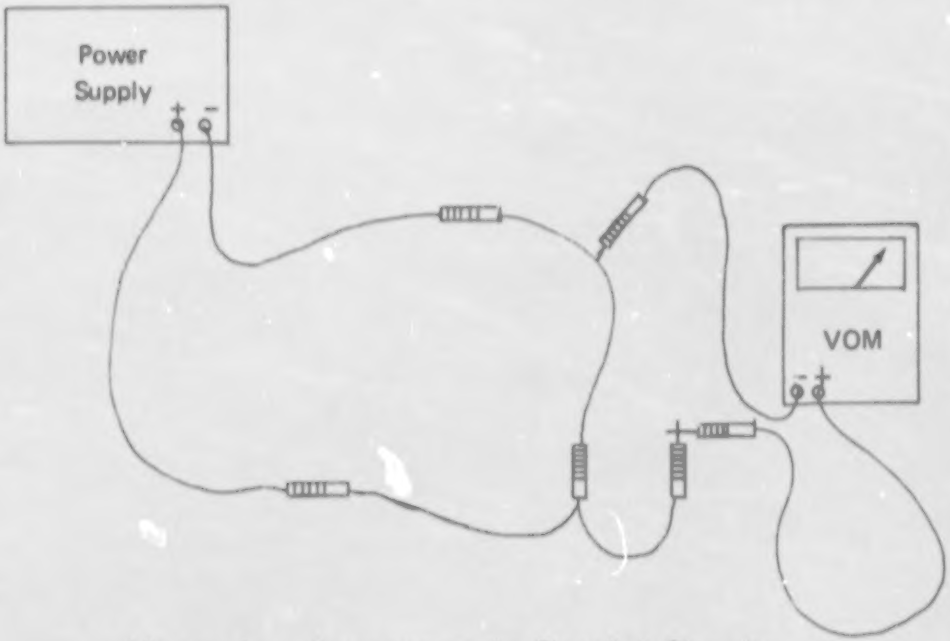



Power
Supply
+ −
VOM
− +

Correct Amperage Measurements

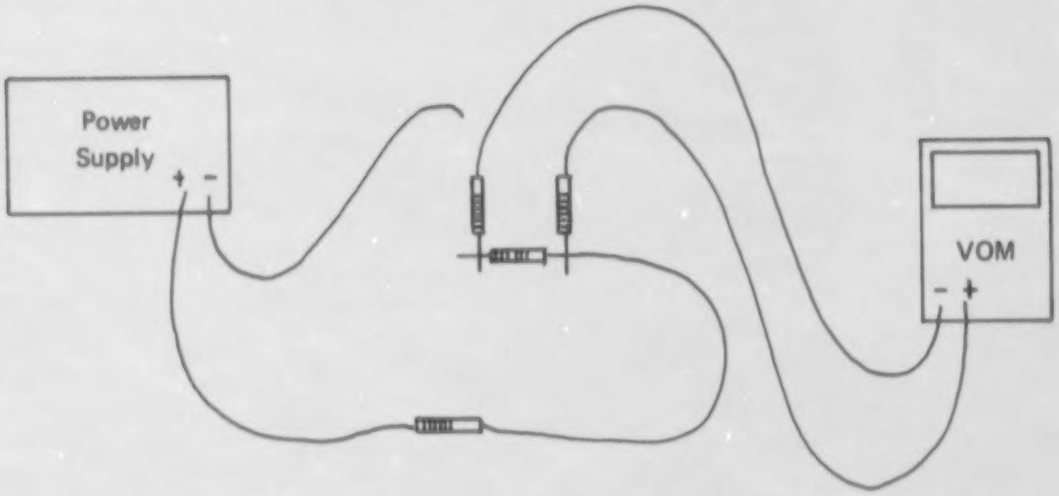

Power
Supply
+ −
VOM
− +
+

Measuring Amperage in Series Circuits

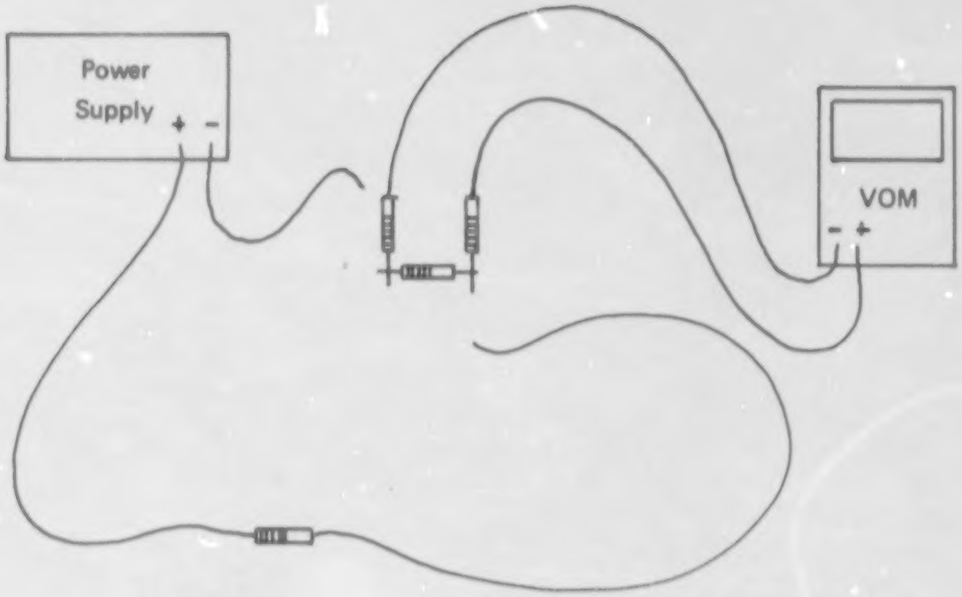

Power
Supply
+ −
VOM
− +
+

Measuring Amperage in Parallel Circuits

Correct Resistance Measurements

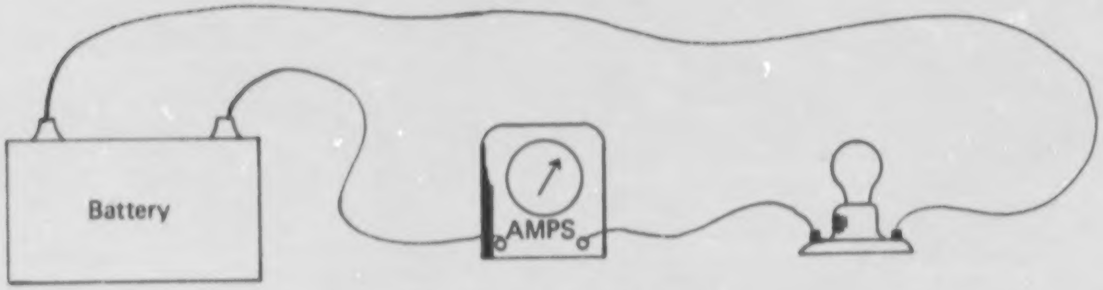

Power
Supply
+ -
VOM
- +

Isolating Component by Removing One Lead

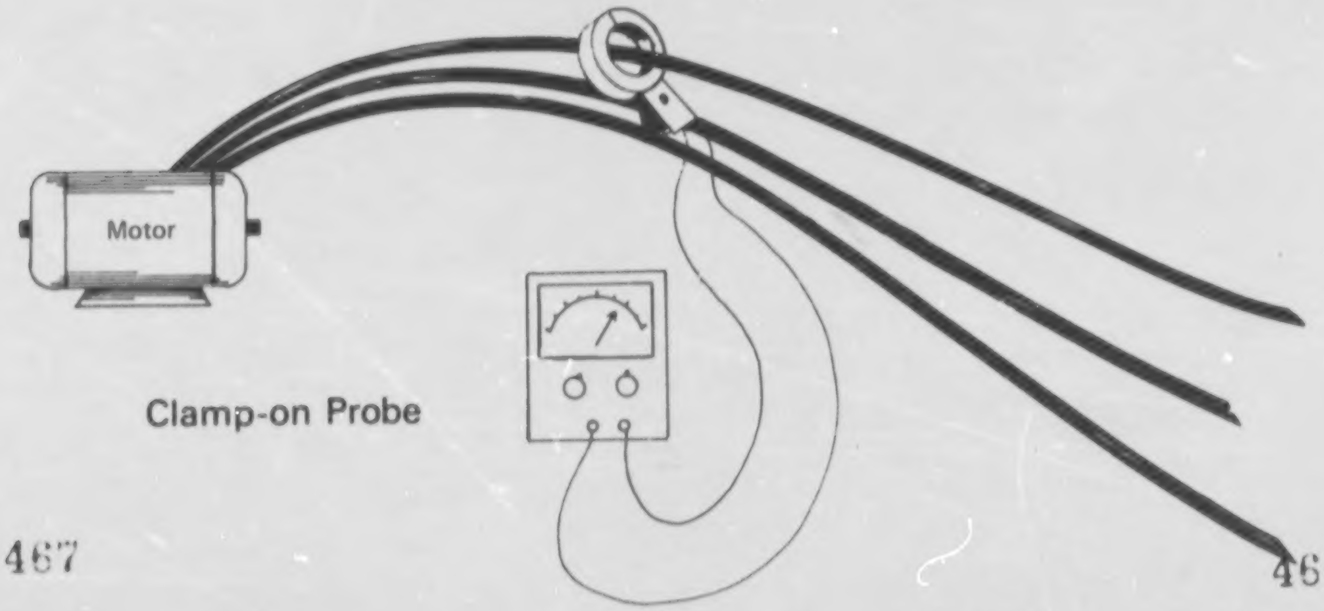

Power
Supply
+ -
VOM
- +

Isolating Component by Removing All Leads

Amperage Measurement Techniques


Battery
AMPS

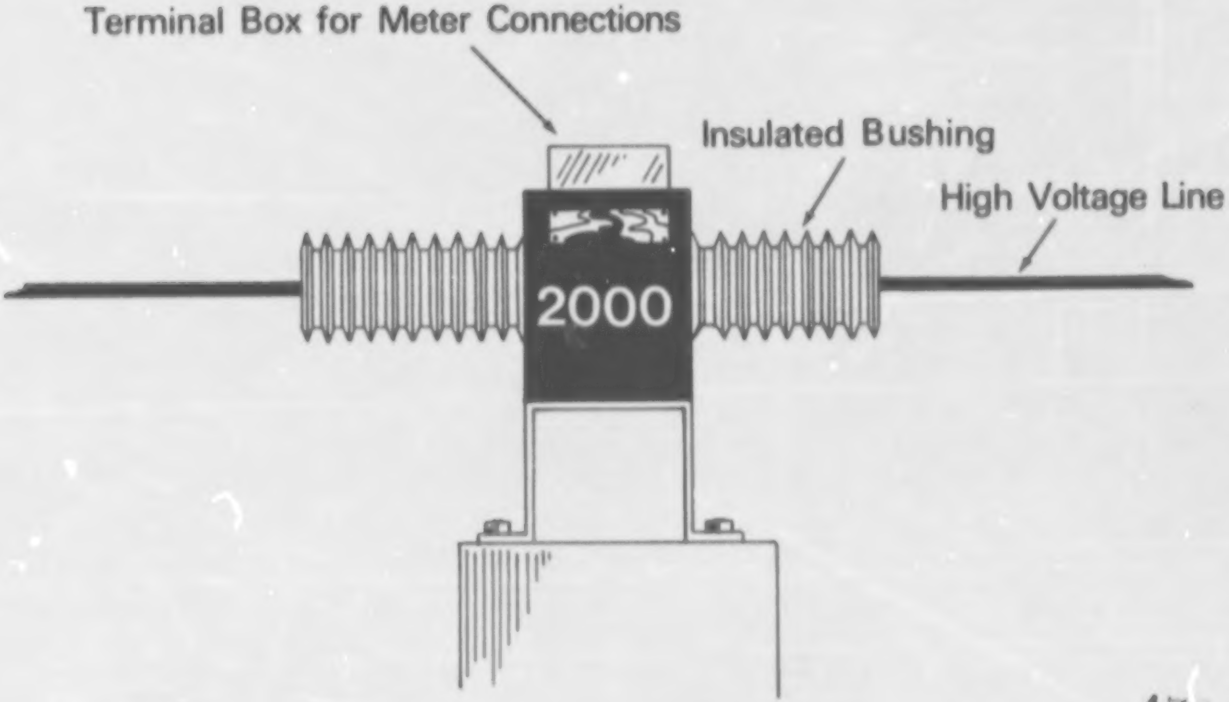
Series Ammeter



Clamp-on Probe

Amperage Measurement Techniques

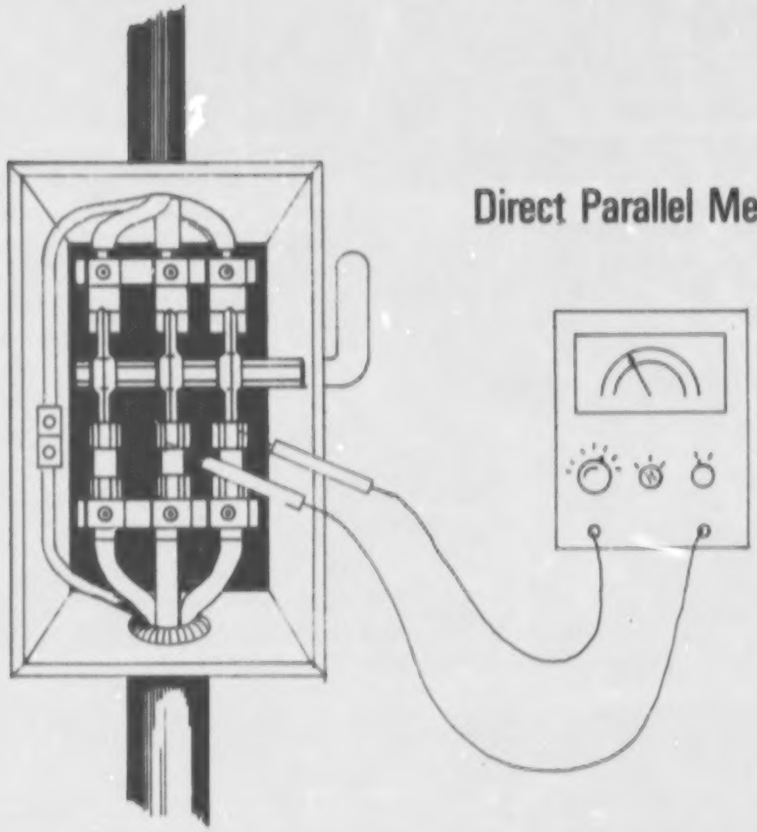
(Continued)


Terminal Box for Meter Connections
Insulated Bushing
High Voltage Line
2000

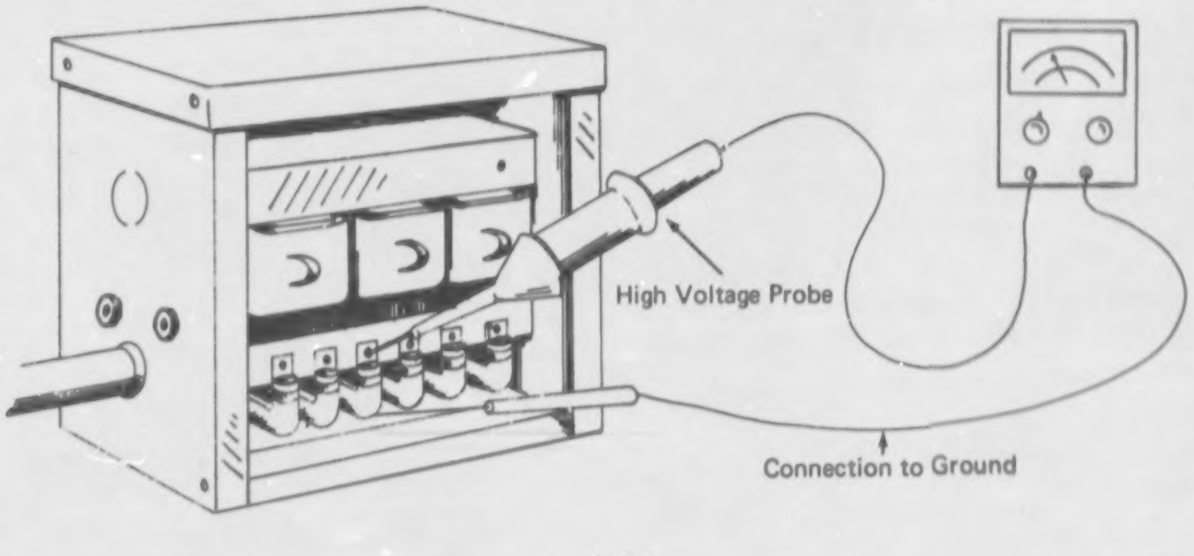
Current Transformer

Voltage Measurement Techniques

Direct Parallel Measurement

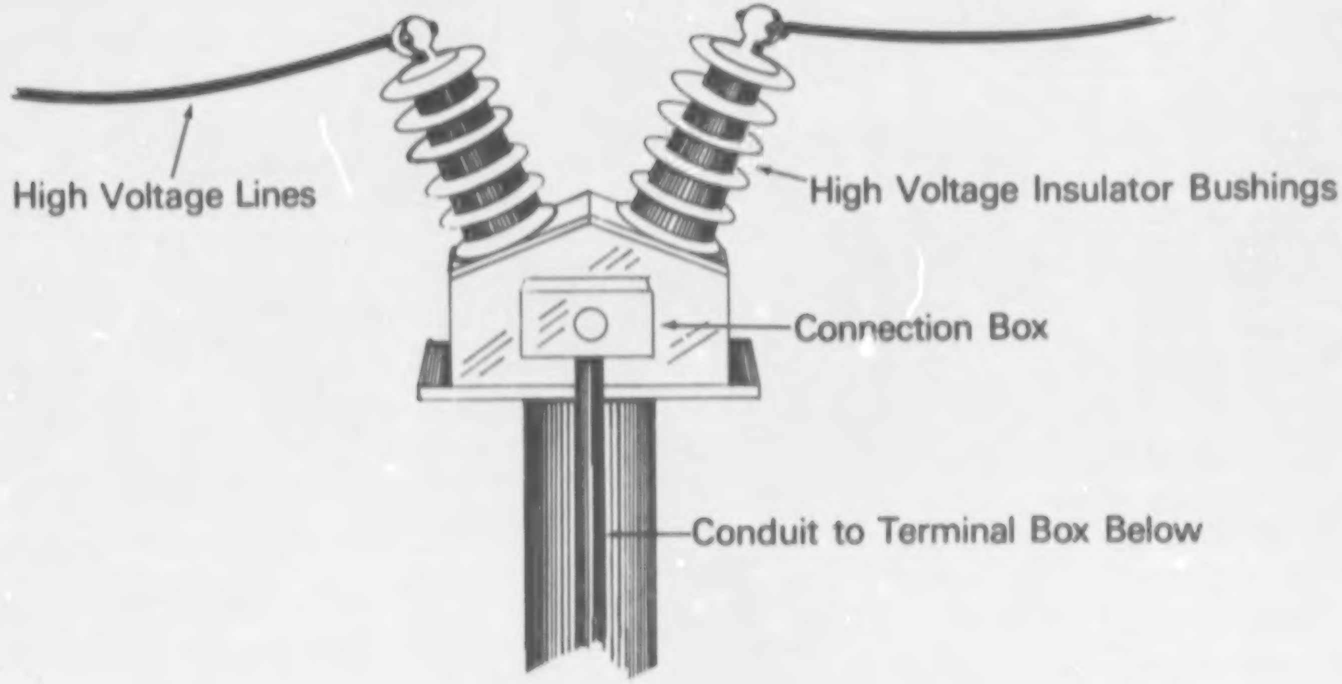


High Voltage Probe


High Voltage Probe
Connection to Ground

Voltage Measurement Techniques

(Continued)


High Voltage Lines
High Voltage Insulator Bushings
Connection Box
Conduit to Terminal Box Below

Potential Transformer

METERS
UNIT I

ASSIGNMENT SHEET #1--COMPUTE AMMETER SHUNT RESISTANCE

NAME ______________________________ SCORE ______________

Sometimes it is necessary to change the range of an ammeter to that of a higher value. Because ammeters generally have built-in shunts, the principle of ammeter shunts also explains how smaller ammeter internal wiring works to measure many amperes of current.

Calculate the shunt resistances required for the ammeter listed below.

An ammeter has a full scale capacity of 1 ampere. The ammeter resistance is .05 ohms. Calculate the shunt resistance necessary to make the ammeter show full-scale when the circuit is carrying a total of 10 amperes. Complete the problem by filling in the steps listed below.

1. Sketch the meter and shunt circuit.

2. What is the voltage across the meter at full-scale amperage? ______________

   (NOTE: E = IR.)

3. What is the current through the shunt at full-scale amperage? ______________

4. What should the shunt resistance be? ______________________

   (NOTE: The low resistance value obtained above indicates why ammeter shunts are often copper straps with little resistance instead of actual resistors.)

5. An ammeter that has had its scale changed should be designated as such. Some ammeters have changeable face plates. For control panels, technicians often indicate that the meter is only showing a part of the current by printing or tagging, "X 10," "X 100," or other such markings. If the ammeter in this problem is indicating .5A, what is the circuit amperage? ______________________

METERS
UNIT I

ASSIGNMENT SHEET #2--COMPUTE VOLTMETER SERIES RESISTANCE

NAME ______________________________ SCORE ______________

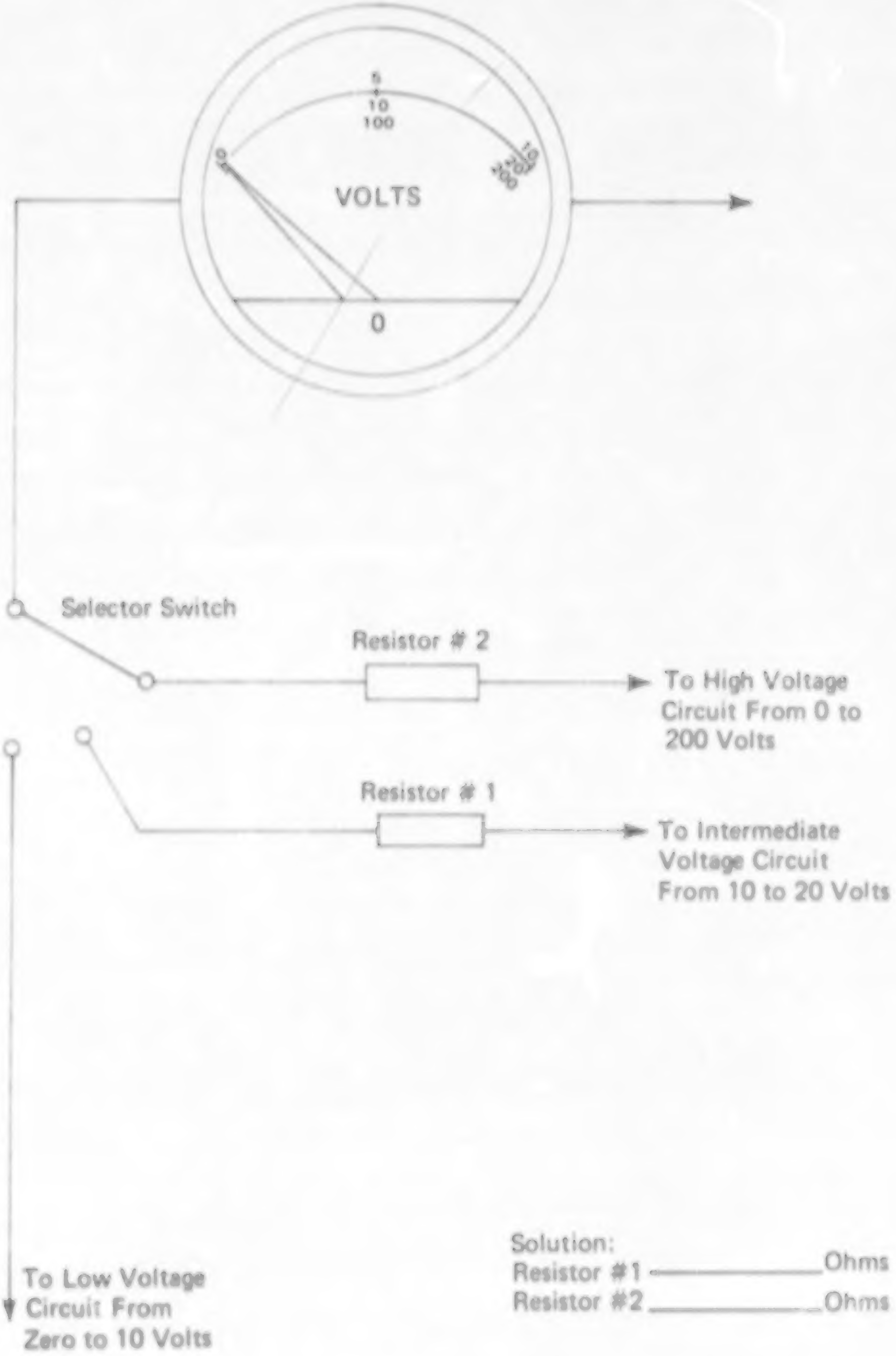
Few meters are designed and built specifically for a particular voltage. Manufacturers and technicians frequently construct a meter for a particular voltage by adding a series resistor to an existing meter with a lower voltage response. The face plate of the meter is changed and renumbered, or a multiplier label such as "X 10" is added. Thus a meter with a full-scale reading of 10 volts could be made to function at 100 volts with the correct sized resistor added in series. The operator would note the multiplier label and interpret a reading of 6 as 60 volts. Some voltmeters are calibrated as tachometers (rpm gauges), liquid level indicators, such as fuel tank gauges, and flow meters.

When plant and equipment changes are made, it may be necessary to change the scale of many of these meters. Special modifications may not allow a specific meter to be readily available from a supplier. It also may be desirable to make a meter of multiple scales by adding a selector switch that selects various series resistors. This is how a multimeter functions through the range control.

For the meter circuit which follows (Figure 5), calcuate the required series resistors to make it read 20 and 200 volts at full-scale, in addition to the original 10 volts full-scale. The meter internal resistance is 5,000 ohms. Show your calculations in the space below and place your answers in the spaces provided on the following sheet. Hand in this material to your instructor for evaluation.

ASSIGNMENT SHEET #2

NAME ______________________


5
10
100
0
10
20
200
VOLTS
0
Selector Switch
Resistor # 2
To High Voltage Circuit From 0 to 200 Volts
Resistor # 1
To Intermediate Voltage Circuit From 10 to 20 Volts
To Low Voltage Circuit From Zero to 10 Volts

Solution:
Resistor #1 ______________ Ohms
Resistor #2 ______________ Ohms

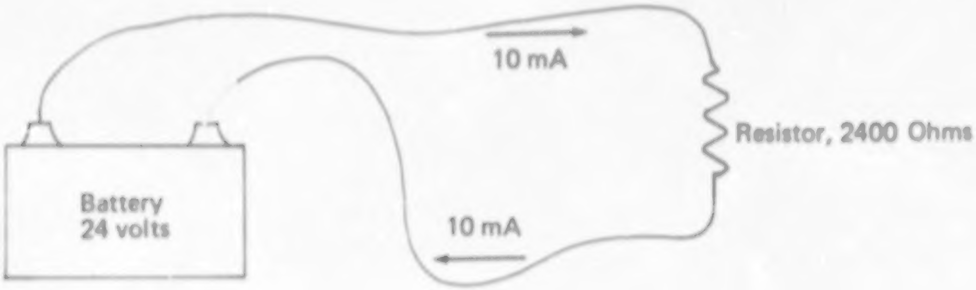
METERS
UNIT I

ASSIGNMENT SHEET #3-DETERMINE AMMETER LOADING EFFECTS

NAME ______________________ SCORE ____________

An ideal ammeter would have zero ohms of resistance, but because most ammeters have some resistance, they will introduce error into the circuit. The simple circuit in Figure 6 below has exactly 10 milliamps of current. Suppose this is not known, however, and a technician places an ammeter in series to measure the current. What current will the ammeter measure if it has resistances as listed in the following problems?

FIGURE 6



1. Ammeter resistance is 600 ohms. Measured current will be ____________

(NOTE: Sketch the complete circuit with the meter and its internal resistance. Use Ohm's Law to find the total resistance.)

ASSIGNMENT SHEET #3

2. Ammeter resistance is 10 ohms. Measured current will be ____________________

(NOTE: Sketch the complete circuit with the meter and its internal resistance. Use Ohm's Law to find the total resistance.)

3. Is the meter in Question #1 accurate? ________________________________

METERS
UNIT I

ASSIGNMENT SHEET #4--DETERMINE VOLTMETER LOADING EFFECTS

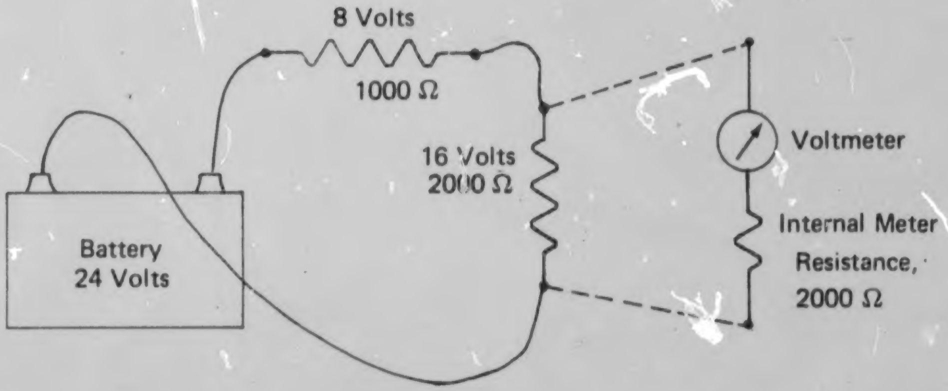
NAME ____________________ SCORE ____________

In the simple circuit shown in Figure 7 below, the voltage across the 2,000 ohm resistor is 16 volts. A technician places a voltmeter parallel to the resistor, as indicated, in order to measure the voltage across it. If the meter resistance is also 2,000 ohms, and if two like resistors in parallel have the effective resistance of one-half of one resistor (1,000 ohms in this case), then what voltage will the technician measure?

Measured voltage = ____________________

(NOTE: Resketch the circuit with two 1,000-ohm resistors and use Ohm's Law to determine the voltage across each.)

FIGURE 7


8 Volts
1000 Ω
16 Volts
2000 Ω
Voltmeter
Internal Meter Resistance, 2000 Ω
Battery
24 Volts

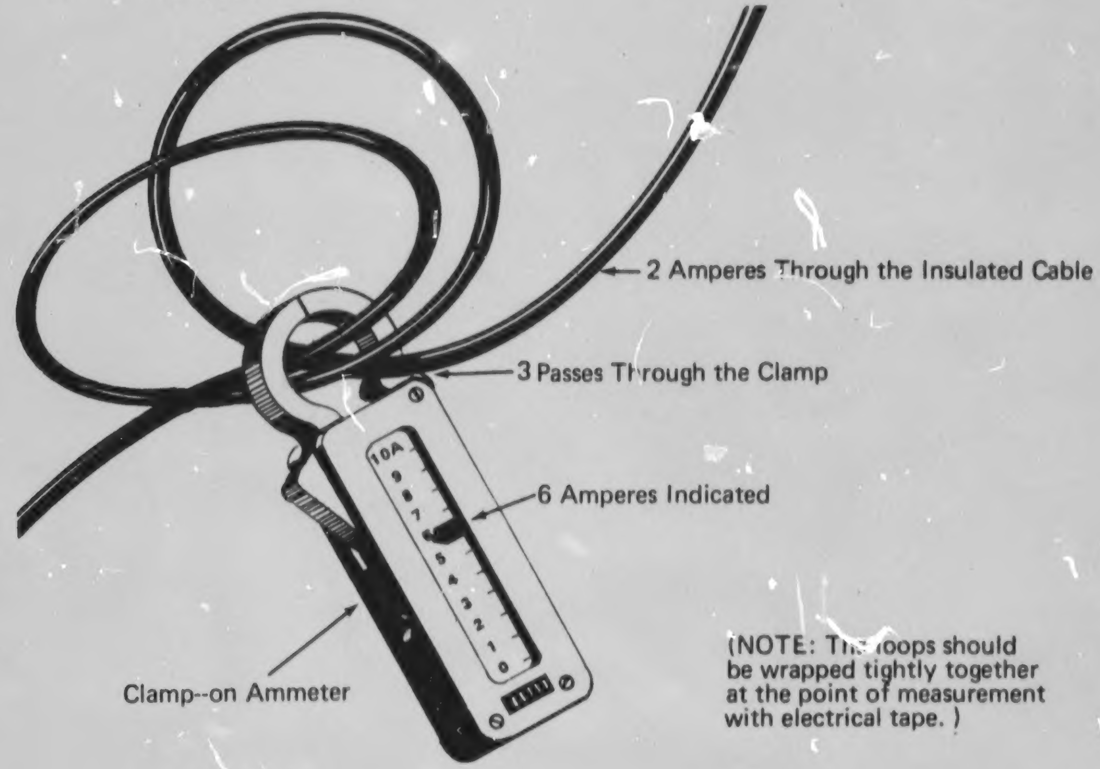
METERS
UNIT I

ASSIGNMENT SHEET #5–DETERMINE THE CURRENT OF A MULTIPLE-LOOP, CLAMP-ON AMMETER APPLICATION

NAME ______________________________ SCORE ______________

To make a clamp-on ammeter or ammeter probe more sensitive, an electrician can make several loops of wire and measure the total amperage of all loops, and then divide the meter reading by the number of loops. This technique is illustrated in Figure 8 below. Determine the actual current in each problem listed below.

FIGURE 8


2 Amperes Through the Insulated Cable
3 Passes Through the Clamp
10A
9
8
7
5
4
3
2
1
0
6 Amperes Indicated
Clamp--on Ammeter

(NOTE: The loops should be wrapped tightly together at the point of measurement with electrical tape.)

1. Four loops of wire produce a reading of 1 ampere. What is the current flow in the conductor expressed in amperes? ______________________

2. Write the answer above expressed in milliamperes______________________

   (NOTE: 1,000 millamperes is equivalent to 1 ampere.)

3. Three loops of wire and a reading of 900 milliamperes indicate a conductor current of how many amperes? ______________________

METERS
UNIT I

ASSIGNMENT SHEET #6--DETERMINE CIRCUIT CHARACTERISTICS THROUGH INDIRECT MEANS

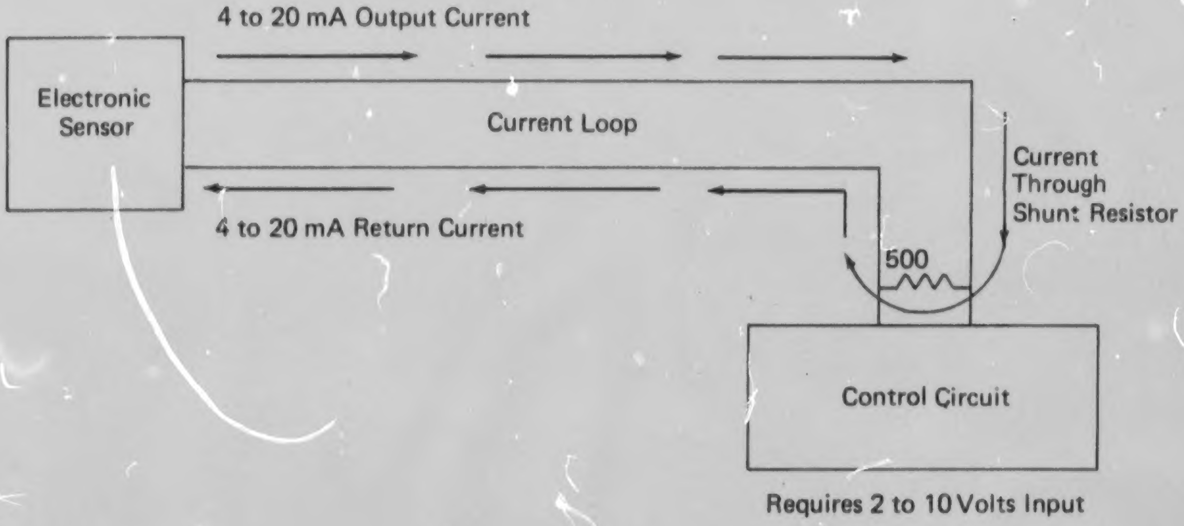
NAME ______________________ SCORE ______________

Industrial control equipment often makes use of Ohm's Law to measure voltage, current, or resistance indirectly.

EXAMPLE: Suppose a sensing element produces from 4 to 20 milliamperes (a standard range), but must control a circuit that functions from 2 to 10 volts. A precision 500 ohm resistor would be placed across the input terminals of the circuit. By Ohm's Law then, 4 mA input would result in 2 volts, and 20 mA input would result in 10 volts. By measuring the voltage of the known resistor, the current can always be determined indirectly.

Answer the following questions related to the circuit given in Figure 9.

FIGURE 9


4 to 20 mA Output Current
Electronic Sensor
Current Loop
Current Through Shunt Resistor
4 to 20 mA Return Current
500
Control Circuit
Requires 2 to 10 Volts Input

1. If the voltage across the resistor measures 6 volts, what is the current flow in milliamperes? ______________________

2. If the voltage across the output terminals of the sensor measures 8 volts, what is the current flow? ______________________

   (NOTE: Ensure that the wires have no resistance back to the resistor.)

METERS
UNIT I

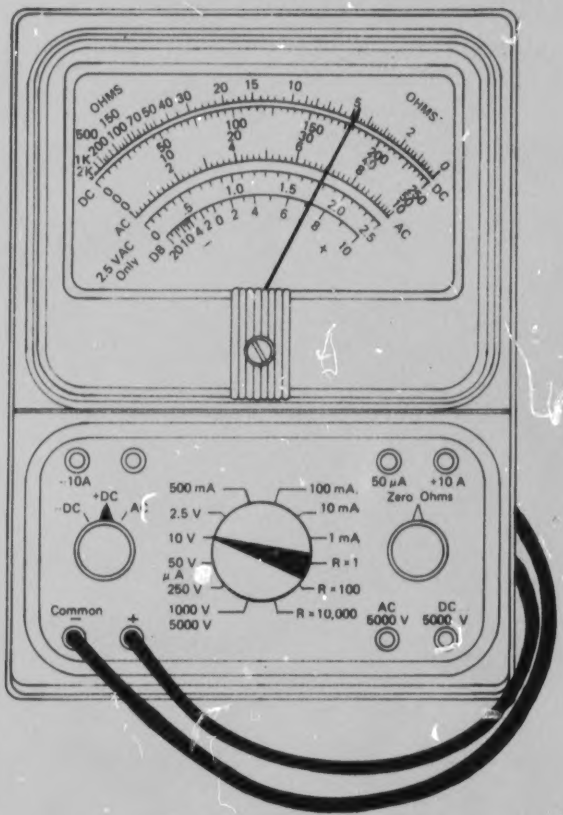
ASSIGNMENT SHEET #7--DETERMINE VARIABLES AND VALUES FROM MULTIMETER CONTROL SETTINGS AND DIAL INDICATIONS

NAME ______________________________ SCORE ______________

A technician may be confronted with various types of multimeters. Since all controls are similar, operation can quickly be mastered. The multimeter in Figures 10-14 may not be the type used in the training program in which you are enrolled, but understanding its controls will help in understanding multimeters in general. For each illustration below, answer the related question.

1.

FIGURE 10


OHMS
OHMS
DC
AC
2.5 VAC Only
DB
-10A
-DC
+DC
AC
500 mA
2.5 V
10 V
50 V
μA
250 V
1000 V
5000 V
100 mA
10 mA
1 mA
R = 1
R = 100
R = 10,000
50 μA
+10 A
Zero Ohms
AC 5000 V
DC 5000 V
Common
−
+

a. Is the meter reading ohms, volts, or amps? ______________________

b. What is the maximum value that the meter can measure at these settings? ______

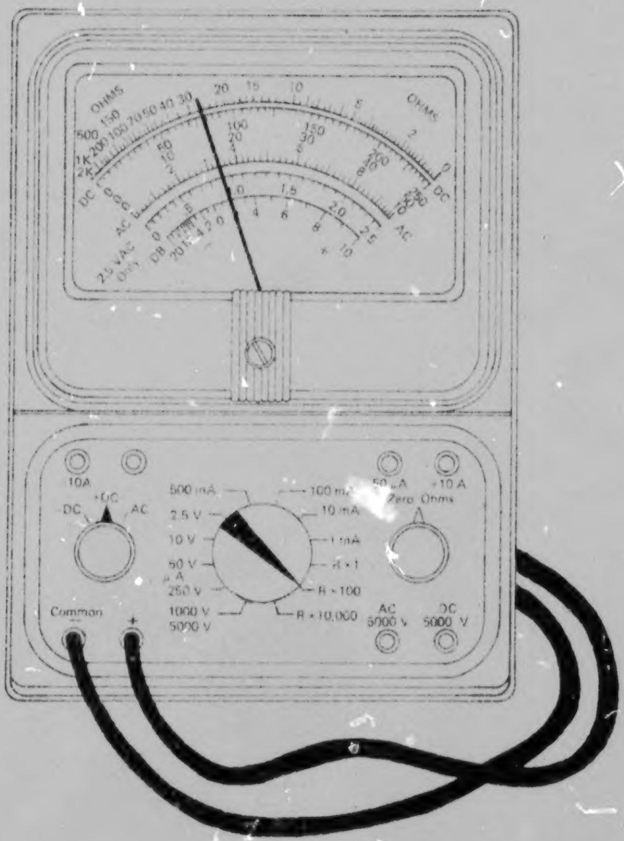
c. Could this measurement be made if the test leads were plugged into any other test jacks ? ______________________________

d. What numerical value is the meter indicating? ______________________

ASSIGNMENT SHEET #7

2.

FIGURE 11


OHMS
500
150
1K
2K
200
100
70
50
40
30
20
15
10
5
2
0
OHMS
DC
AC
2.5 VAC ONLY
DB
10A
-DC
+DC
AC
500 mA
2.5 V
10 V
50 V
μA
250 V
1000 V
5000 V
100 mA
10 mA
1 mA
R × 1
R × 100
R × 10,000
50 μA
+10 A
Zero Ohms
AC
5000 V
DC
5000 V
Common
-
+

a. Is the meter reading ohms, volts, or amps? ____________________

b. Could this measurement be made if the test leads were plugged into any other jacks? ____________________

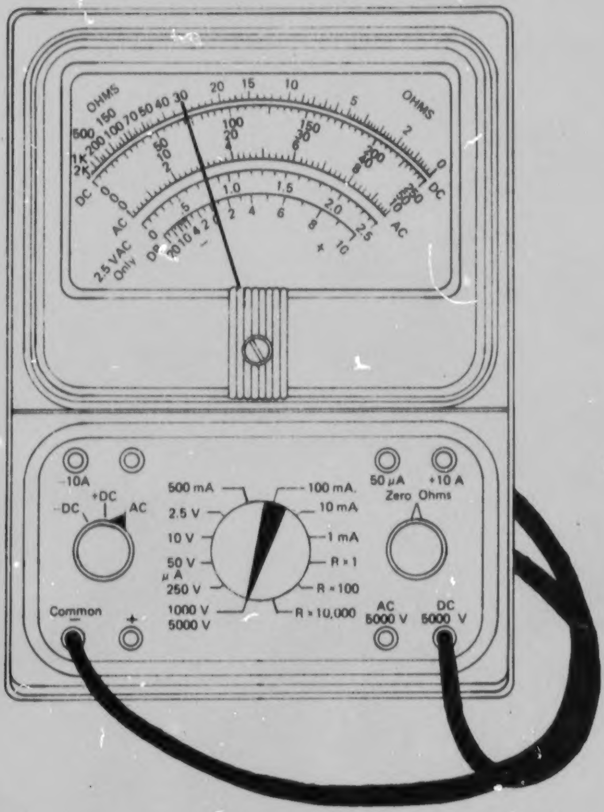
c. What numerical value is the meter indicating? ____________________

d. What adjustment should have been made before making this measurement? ____________________

ASSIGNMENT SHEET #7

3.

FIGURE 12


OHMS
500
150
1K
200
100
70
50
40
30
20
15
10
5
2
0
2K
DC
AC
2.5 VAC Only
1.0
1.5
2.0
2.5
x 10
-10A
+DC
-DC
AC
500 mA
2.5 V
10 V
50 V
μA
250 V
1000 V
5000 V
100 mA
10 mA
1 mA
R x 1
R x 100
R x 10,000
50 μA
+10 A
Zero Ohms
Common
AC
5000 V
DC
5000 V

a. Is the meter reading ohms, volts, or amps? ____________________

b. Is the value AC or DC? ____________________

c. Could this measurement be made if the test leads were plugged into any other test jacks? ____________________

d. What numerical value is the meter indicating? ____________________

METERS
UNIT I

ASSIGNMENT SHEET #8--SET MULTIMETER CONTROLS FOR MEASUREMENTS

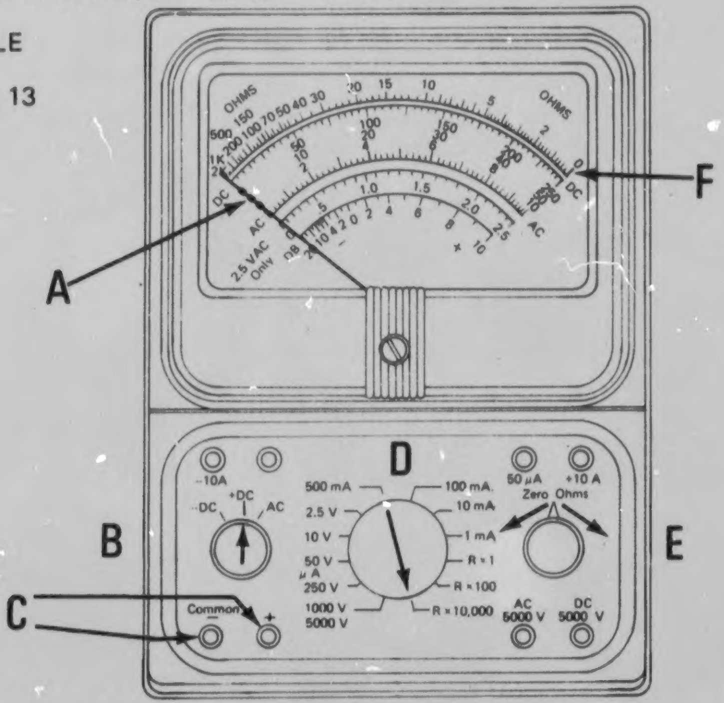
NAME ______________________________ SCORE ________________

PART I

If a technician does not place meter controls in the correct position, erroneous readings may be made, the meter may be damaged, the equipment being measured may short circuit, or the technician may be injured in the event that high voltage causes the meter to explode. In the following illustrations (Figures 14-16) make arrows pointing to the control positions, test jack connections, and appropriate scale.

EXAMPLE

FIGURE 13



A
B
C
D
E
F
OHMS
DC
AC
2.5 VAC Only
dB
-10A
+DC
-DC
AC
Common
+
500 mA
2.5 V
10 V
50 V
μA
250 V
1000 V
5000 V
100 mA
10 mA
1 mA
R × 1
R × 100
R × 10,000
50 μA
+10 A
Zero Ohms
AC 5000 V
DC 5000 V

(NOTE: The meter is shown as set to make ohms measurement of a high value resistance.)

A. The "Meter Zero" is checked with no inputs applied.

B. The "Function" selector is set for + DC.

C. The test leads are plugged into these jacks.

D. The range switch is set to "R x 10,000."

E. The leads are connected and the "Zero Ohms" is adjusted, if necessary.

ASSIGNMENT SHEET #8

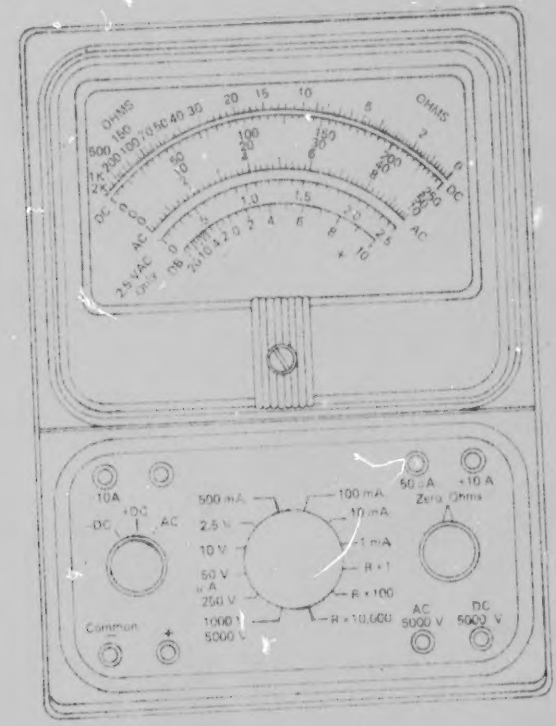
F. The top scale will be read.

(NOTE: For the following problems, merely make indications with arrows. An explanation will not be necessary.)

PART II

A. Indicate in Figure 14 below, meter controls, jacks, and scale for measuring 250 mA. + DC.

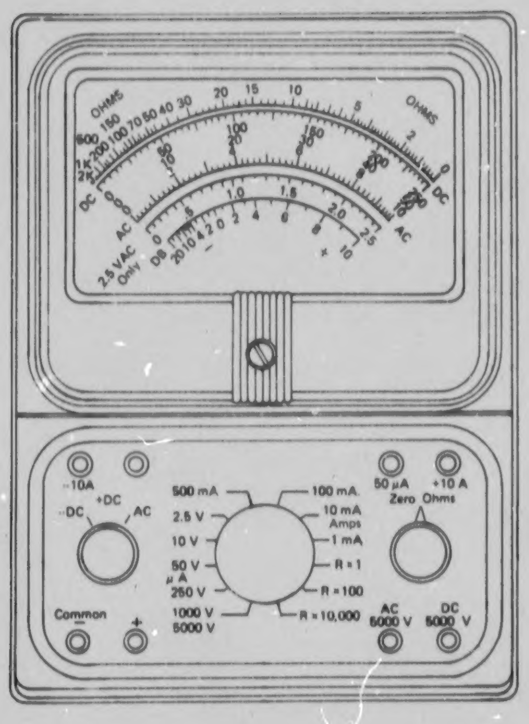
FIGURE 14


OHMS
20
15
10
5
OHMS
2
0
DC
AC
2.5 VAC
DB
10A
+DC
-DC
AC
500 mA
2.5 V
10 V
50 V
μA
250 V
1000 V
5000 V
100 mA
10 mA
1 mA
R × 1
R × 100
R × 10,000
50 μA
+10 A
Zero Ohms
AC
5000 V
DC
5000 V
Common
−
+

ASSIGNMENT SHEET #8

B. Indicate in Figure 15 below, meter controls, jacks, and scale for measuring +10A DC.

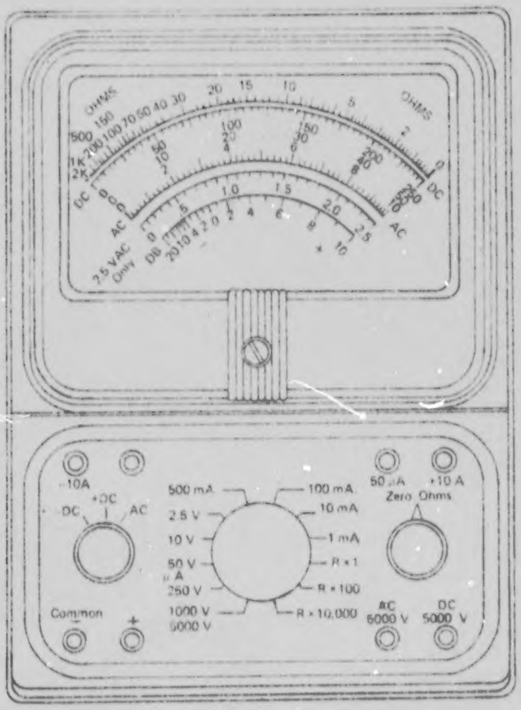
FIGURE 15


OHMS
DC
AC
2.5 VAC Only
DB
−10A
+DC
−DC
AC
Common
−
+
500 mA
2.5 V
10 V
50 V
μA
250 V
1000 V
5000 V
100 mA
10 mA
Amps
1 mA
R × 1
R × 100
R × 10,000
50 μA
+10 A
Zero Ohms
AC 5000 V
DC 5000 V

ASSIGNMENT SHEET #8

C. Indicate in Figure 16 below, meter controls, jacks, and scale for measuring 100V AC.

FIGURE 16

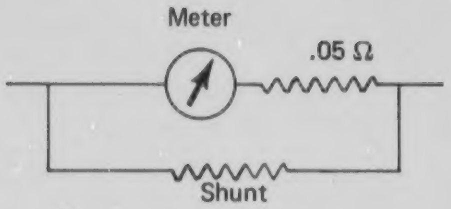

OHMS
OHMS
DC
DC
AC
AC
2.5 VAC Only
DB
−10A
−DC
+DC
AC
Common
−
+
500 mA
2.5 V
10 V
50 V
μA
250 V
1000 V
5000 V
100 mA
10 mA
1 mA
R × 1
R × 100
R × 10,000
50 μA
+10 A
Zero Ohms
AC 5000 V
DC 5000 V

METERS
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1.



2. .05 volts
3. 9 amperes
4. .00556 ohms or 5.56 milliohms
5. 5 amperes

Assignment Sheet #2

1. Resistor #1 = 5,000 ohms
2. Resistor #2 = 95,000 ohms

Assignment Sheet #3

1. 8 mA or .008 amperes

   (NOTE: The total resistance is (600 + 2400) or 3000 ohms.)
2. 9.96 mA or .00996
3. No

Assignment Sheet #4

Measured voltage = 12 volts

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #5

1. .25 amperes or 1/4 ampere
2. 250 milliamperes
3. .3 amperes

Assignment Sheet #6

1. 12 mA
2. 16 mA

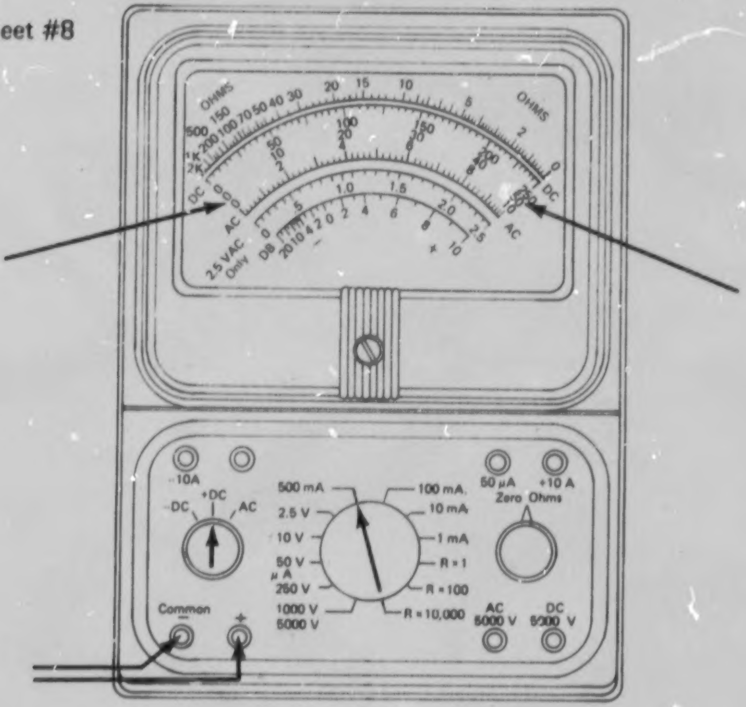
Assignment Sheet #7

1. a. Volts
   b. 10 volts
   c. No
   d. 7.2 volts
2. a. Ohms
   b. No
   c. 2600 ohms
   d. Zero ohms
3. a. Volts
   b. AC
   c. No
   d. 1500 volts

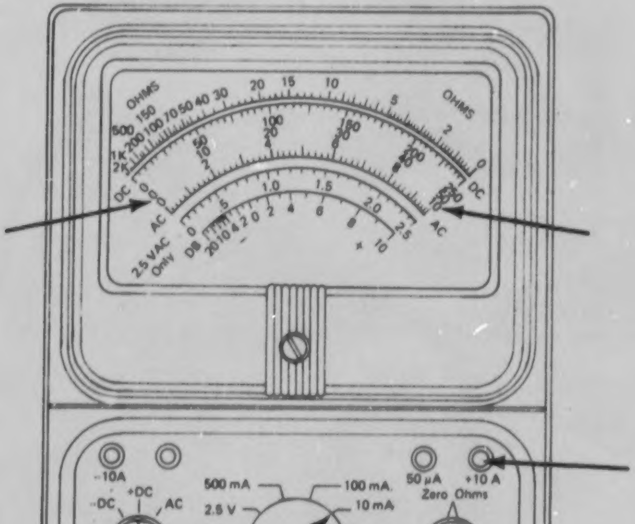
ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #8

A.

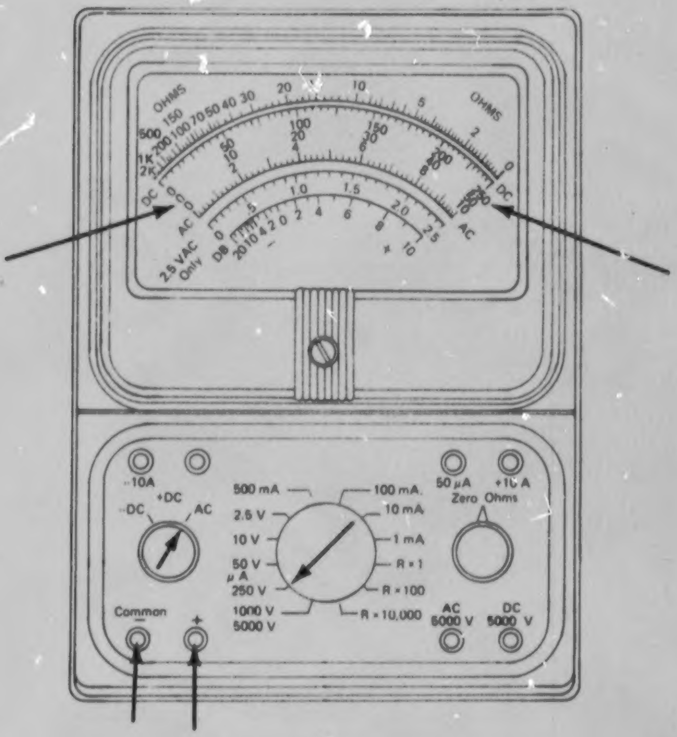

OHMS
DC
AC
2.5 VAC Only
DB
-10A
+DC
-DC
AC
500 mA
2.5 V
10 V
50 V
μA
250 V
1000 V
5000 V
100 mA
10 mA
1 mA
R = 1
R = 100
R = 10,000
50 μA
+10 A
Zero Ohms
Common
+
AC 5000 V
DC 5000 V

B.


OHMS
DC
AC
2.5 VAC Only
DB
-10A
+DC
-DC
AC
500 mA
2.5 V
10 V
50 V
μA
250 V
1000 V
5000 V
100 mA
10 mA
1 mA
R = 1
R = 100
R = 10,000
50 μA
+10 A
Zero Ohms
Common
+
AC 5000 V
DC 5000 V

ANSWERS TO ASSIGNMENT SHEETS

C.


OHMS
500
150
1K
2K
200
100
70
50
40
30
20
10
5
2
0
OHMS
DC
AC
2.5 VAC Only
DB
1.0
1.5
2.0
2.5
x 10
-10A
+DC
-DC
AC
500 mA
2.5 V
10 V
50 V
μA
250 V
1000 V
5000 V
100 mA
10 mA
1 mA
R × 1
R × 100
R × 10,000
50 μA
+10 A
Zero Ohms
AC 5000 V
DC 5000 V
Common
−
+

METERS
UNIT I

JOB SHEET #1–MEASURE DIRECT CURRENT VOLTAGE SOURCES USING A MULTIMETER

I. Equipment and materials

   A. Multimeter with test leads

   B. DC power source (power supply or battery)

II. Procedure

   A. Turn power supply on

   B. Adjust the output to any voltage less than 50 volts

   C. Set multimeter controls for measuring DC volts

   D. Measure voltage of the DC source

   E. Record results below

   DC source = ______________________________

   Voltage reading = ______________________________

   F. Change the source voltage (or measure a second battery), but do not go over 50 volts

   DC source = ______________________________

   Voltage reading = ______________________________

   (NOTE: Show your results to the instructor.)

   G. Put equipment and materials away

METERS
UNIT I

JOB SHEET #2--MEASURE DIRECT CURRENT CIRCUIT VOLTAGES USING A MULTIMETER

I. Equipment and materials

A. Multimeter with test leads

B. Resistors--4, values specified by instructor

C. "On/off" switch

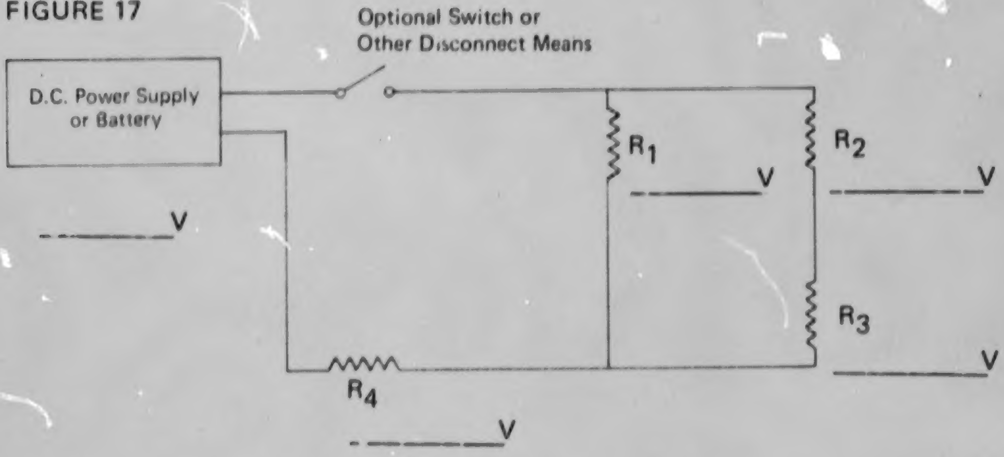
D. Direct current power source

E. Circuit board or proto board

II. Procedure

A. Assemble resistor network with series and parallel resistors as shown in Figure 17 below

FIGURE 17


Optional Switch or
Other Disconnect Means
D.C. Power Supply
or Battery
R$_1$
____V
R$_2$
____V
____V
R$_3$
____V
R$_4$
____V

B. Have instructor specify power supply voltage to be used

C. Calculate voltages across the resistors indicated in circuit (Figure 17)

D. Adjust power supply for specified voltage

(NOTE: Do not connect power supply to circuit. Have the instructor check circuit and power source.)

E. Be sure power supply is turned off; connect to circuit

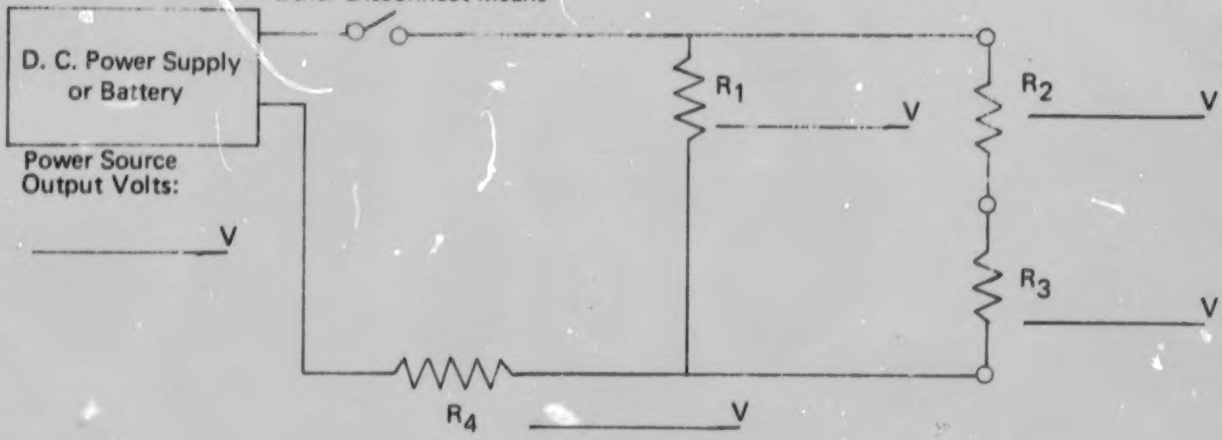
F. Turn on power supply

JOB SHEET #2

G. Turn on switch in circuit

H. Measure voltages across components indicated in Figure 18

FIGURE 18


Optional Switch or
Other Disconnect Means
D. C. Power Supply or Battery
Power Source Output Volts:
______V
R1 ______V
R2 ______V
R3 ______V
R4 ______V

I. Record your measurements on the diagram

(NOTE: Show results to the instructor.)

J. Complete Job Sheet #3 before taking apart circuit

METERS
UNIT I

JOB SHEET #3--MEASURE DIRECT CURRENT AMPERES IN A CIRCUIT USING A MULTIMETER

I. Equipment and materials

A. Multimeter with test leads

B. DC power source--With preset output and appropriate connecting cables

C. Resistor network--Series and parallel resistors similar or identical to those used in Job Sheet #2

II. Procedure

A. Set multimeter for DC amperage measurement

B. Be sure power supply is turned off

C. Connect multimeter into the circuit where the total circuit current can be measured

(NOTE: Have instructor check circuit.)

D. Turn on power source and record the amperage reading below

Total current = ______________________________

E. Turn off power source and reconnect meter to read the current through one of the parallel resistors

(NOTE: Have instructor check circuit.)

F. Turn power source back on and record that reading below

1st parallel resistor current ______________________________

G. Repeat steps E and F for second parallel resistor

2nd parallel resistor current ______________________________

(NOTE: Show your results to the instructor.)

H. Put equipment and materials away

METERS
UNIT I

JOB SHEET #4--MEASURE ALTERNATE CURRENT VOLTAGES USING A MULTIMETER

I. Equipment and materials

A. Multimeter with test leads

B. Alternate current power sources

EXAMPLES: 24-volt transformer, rheostat, variac

II. Procedure

A. Set multimeter controls to measure AC volts

B. Measure "line voltage" of power receptacle at the work bench (See Figure 19)

(CAUTION: 120 volts can cause injury or death. Do not touch the metal parts of the test leads while measuring.)

C. Record the readings below

1. Voltage between slotted jacks ______________________

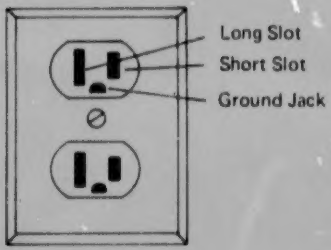
2. Voltage between longest slotted jack and ground jack ______________

____

3. Voltage between short slotted jack and ground jack ______________

____

FIGURE 19



(NOTE: If voltage is measured in Step 2, the receptacle is wired incorrectly. Notify your instructor.)

D. Attach the equipment given to you by the instructor to specified power source

JOB SHEET #4

E. Measure output voltages

F. Record data below for those devices specified by your instructor

1. Variac voltage at setting specified by instructor ____________________
2. Transformer output voltage ____________________________________
3. Rheostat output voltage at setting specified by instructor __________

   ____
4. Other device or source of AC voltage
   - a. Name ____
   - b. Voltage ____

   (NOTE: Show your results to the instructor.)

G. Put equipment and materials away

METERS
UNIT I

JOB SHEET #5--MEASURE THREE-PHASE ALTERNATING CURRENT POWER USING A MULTIMETER

I. Equipment and materials

A. Multimeter with test leads

B. Source of three-phase AC power such as a fused disconnect power distribution panel (Transparency #7, Part A)

C. Safety glasses

II. Procedure

(NOTE: Instructor must individually supervise each student.)

A. Set multimeter for AC voltage measurement

(NOTE: Have the instructor check your settings.)

B. With the instructor watching, carefully measure between each of the three terminals at the top of the box and a ground terminal; record your measurements below

Voltage from terminals to ground

1. ______________________________

2. ______________________________

3. ______________________________

C. Measure between the first and second, first and third, and second and third terminals; record the readings below

Voltages between terminals

1 to 2 ______________________________

1 to 3 ______________________________

2 to 3 ______________________________

(NOTE: Show your measurements to the instructor.)

D. Put equipment and materials away

METERS
UNIT I

JOB SHEET #6--MEASURE ALTERNATING CURRENT USING A MULTIMETER

I. Equipment and materials

A. Multimeter with test leads

B. Lamp base--120 VAC

C. Lamp--40 to 150 watts

D. Lamp cord with 120 volt plug

II. Procedure

A. Connect lamp, multimeter, and plug in series

(NOTE: Have instructor check your circuit.)

B. Set multimeter for AC amperage measurement

C. Plug circuit into 120 VAC receptacle, and measure the current; record measurement below

Lamp current = ____________________________amps

D. Multiply amperage reading obtained in this job sheet by the voltage reading obtained in Job Sheet #4, C #1; record below

Amps x volts = ____________________________watts

E. Answer the questions below

1. Is the quantity obtained in Step F amps, volts, ohms, watts, or kilowatts? ____

2. What is the power rating of the lamp? ____________________________

METERS
UNIT I

JOB SHEET #7--MEASURE RESISTANCE USING A MULTIMETER

I. Equipment and materials

A. Multimeter with test leads

B. Various resistors wrapped in masking tape to conceal their values, and numbered for reference

II. Procedure

A. Set multimeter for resistance measurement

B. Measure each resistor provided by your instructor

C. Record the values below

Resistor #1 ______________________________

Resistor #2 ______________________________

Resistor #3 ______________________________

Resistor #4 ______________________________

Resistor #5 ______________________________

(NOTE: Show your results to the instructor.)

D. Put equipment and materials away

(NOTE: Do not leave or store a multimeter in the resistance measuring position. The batteries will lose power. Always make sure that electronic multimeters are turned off.)

METERS
UNIT I

TEST

NAME ______________________________ SCORE ________________

1. Match terms associated with multimeters to their correct definitions. Write the correct numbers in the blanks.

_____a. Instrument consistency

_____b. Circuit that bypasses another circuit or device, especially a low-resistance bypass for an ammeter circuit

_____c. How well the instrument will indicate a small change in the measured value

_____d. How far the measurement is from the actual value

_____e. How near the instrument reading is to the actual value

_____f. How well an instrument responds to small measurements or small changes in the value being measured

_____g. Instrument capable of measuring a "multiple" of values

_____h. Opposition to electrical current flow; impedance; measured in units of ohms; must be measured from one point to another

_____i. Electromotive force (emf); force that drives electricity through conductors; must be measured across, between, or be referenced to a second point

_____j. Electrical point or any good conductor that is connected to a common chassis with zero relative voltage; usually, conductors are connected to the earth

_____k. Technique of testing and adjusting an instrument by referencing it to another instrument or device of known accuracy and precision

_____l. Electricity; electrical current flow; electron flow; must be measured at a point within a circuit

1. Accuracy
2. Precision
3. Sensitivity
4. Resolution
5. Error
6. Calibration
7. Multimeter
8. Branch circuit
9. Shunt
10. Internal resistance
11. Ground
12. Voltage
13. Amperage
14. Resistance

TEST

______ m. Total resistance offered by a device

______ n. Circuit originating from a main circuit, often one of many; one of several parallel circuits

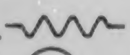
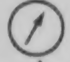
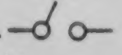
2. Name the two common types of multimeters.

a. ____________________

b. ____________________

3. Match symbols and abbreviations associated with multimeters to their correct interpretations. Write the correct numbers in the blanks.

______ a. Milli
______ b. Digital multimeter
______ c. Alternating current
______ d. Kilo
______ e. Voltohmmeter
______ f. Direct current
______ g. Ohm
______ h. Amp
______ i. Vacuum tube voltmeter
______ j. Volt
______ k. Micro
______ l. Mega
______ m. Resistance
______ n. Decibel
______ o. Switch
______ p. Meter
______ q. Resistance times one hundred
______ r. Resistor
______ s. Light emitting diode

1. VOM
2. DMM
3. VTVM
4. Ω
5. V
6. A
7. m
8. K
9. M
10. μ
11. AC
12. DC
13. R
14. R x 100
15. LED
16. DB
17. 
18. 
19. 

TEST

4. List general steps used in preparing a multimeter for operation.

a. ____

b. ____

c. ____

d. ____

5. Arrange in order procedures for measuring voltage. Write a "1" before the first step, a "2" before the second step, and so on.

______a. Observing polarity, connect meter leads to circuit to be tested

______b. Read correct voltage

______c. Position meter to correct function

______d. Set meter on lowest scale at which it will register

______e. Observing polarity, connect meter leads to meter

______f. Turn off meter

______. Disconnect meter leads

______h. Determine correct range scale

6. Arrange in order procedures for measuring amperage. Write a "1" before the first step, a "2" before the second step, and so on.

______a. Position meter to correct scale

______b. Turn off power to circuit under test

______c. Observe meter reading

______d. Determine correct range

______e. Turn on equipment under test

______f. Turn off meter

______g. Reconnect circuit

______h. Disconnect meter

______i. Hook meter in circuit to be tested, observing polarity and connecting in series with the circuit

______j. Observing polarity, connect test leads to meter

______k. Determine correct amperage reading

TEST

_____l. Turn off power to equipment

_____m. Position range switch to correct scale for most accurate reading

7. Arrange in order procedures for measuring resistance. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. Position meter to the correct function position

_____b. Turn off power to circuit under test

_____c. Reconnect component in circuit

_____d. Remove meter leads

_____e. Turn off meter

_____f. Reconnect meter to component

_____g. Read meter for ohmic value

_____h. Remove leads from component and touch (short) leads together while using "Ohms Zero Adjust" to position meter to the zero position

_____i. Determine correct meter position closest to center scale or toward zero

_____j. Connect meter across component to be measured

_____k. Isolate component to be checked

_____l. Insert meter leads in correct meter jacks, observing polarity

_____m. Position meter range switch to one of the resistance scales

8. Distinguish between characteristics of ammeters and voltmeters. Write an "A" before characteristics of ammeters, and a "V" before characteristics of voltmeters.

_____a. Low impedance to current flow

_____b. Range can be increased by adding a series resistance

_____c. Measures across the circuit or device

_____d. High impedance to current flow

_____e. Range can be increased by adding a parallel (shunt) resistance

_____f. Measures in series with the circuit or device

TEST

9. Match amperage measurement techniques to their correct descriptions. Write the numbers in the blanks.

______a. Measurement equipment isolated from main conductor; technique used for high voltage and high current alternating current applications

______b. All current passes through the ammeter; technique limited to small measurements; alternating current or direct current can be measured

______c. Amperage is gauged by strength of magnetic field around the conductor; technique limited to moderate alternating current voltages and moderate current values

1. Directly in series
2. Clamp-on probe
3. Current transformer

10. Match voltage measurement techniques to their correct descriptions. Write the numbers in the blanks.

______a. Voltmeter probes connect directly across terminals; limited to moderate AC or DC voltages

______b. Voltmeter connects to a device that isolates the voltmeter from the primary source and produces only a fraction of the voltage to be measured; used in measuring very high AC voltages, usually in electrical substations

______c. Voltmeter connects through a high resistance device which limits current and drops the voltage; limited to high AC or DC voltages

1. Direct parallel measurement
2. High voltage probe
3. Potential transformer

11. Compute ammeter shunt resistance in the problem below.

An ammeter indicated full-scale at 100 milliamperes (.1 ampere), and its internal resistance is 5 ohms. What shunt resistor would be necessary to make the full scale reading equivalent to 300 milliamperes? ______________________________

TEST

12. Compute voltmeter series resistance in the problem below.

    A voltmeter reads full-scale at 30 volts. Its internal resistance is 15,000 ohms (15k ohms). What resistor should be placed in series with it to cause it to read full-scale at 150 volts? ______________________________

(NOTE: Test questions 13-19 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

13. Compute ammeter shunt resistance.
14. Compute voltmeter series resistance.
15. Determine ammeter loading effects.
16. Determine voltmeter loading effects.
17. Determine the current of a multiple-loop, clamp-on ammeter application.
18. Determine circuit characteristics through indirect means.
19. Determine variables and values from multimeter control settings and dial indications.
20. Set multimeter controls for measurements.
21. Demonstrate the ability to
    a. Measure direct current voltage sources using a multimeter.
    b. Measure direct current circuit voltages using a multimeter.
    c. Measure direct current amperes in a circuit using a multimeter.
    d. Measure alternating current voltages using a multimeter.
    e. Measure three-phase, alternating current power using a multimeter.
    f. Measure alternate current using a multimeter.
    g. Measure resistance using a multimeter.

METERS
UNIT I

ANSWERS TO TEST

1. a. 2
   b. 9
   c. 4
   d. 5
   e. 1
   f. 3
   g. 7
   h. 14
   i. 12
   j. 11
   k. 6
   l. 13
   m. 10
   n. 8

2. a. Permanent magnet moving coil
   b. Digital

3. a. 7
   b. 2
   c. 11
   d. 8
   e. 1
   f. 12
   g. 4
   h. 6
   i. 3
   j. 5
   k. 10
   l. 9
   m. 13
   n. 16
   o. 19
   p. 18
   q. 14
   r. 17
   s. 15

4. a. Select function to be measured
   b. Select the range or anticipated limits of measurement required
   c. Connect test leads to proper test jacks
   d. Make necessary meter adjustments

5. a. 4
   b. 6
   c. 1
   d. 5
   e. 2
   f. 8
   g. 7
   h. 3

ANSWERS TO TEST

6. a. 2
   b. 1
   c. 7
   d. 3
   e. 6
   f. 13
   g. 12
   h. 11
   i. 5
   j. 4
   k. 9
   l. 10
   m. 8

7. a. 2
   b. 1
   c. 13
   d. 11
   e. 12
   f. 9
   g. 10
   h. 8
   i. 7
   j. 6
   k. 5
   l. 4
   m. 3

8. a. A
   b. V
   c. V
   d. V
   e. A
   f. A

9. a. 3
   b. 1
   c. 2

10. a. 1
    b. 3
    c. 2

11. 2.5 ohms

12. 60,000 ohms or 60K ohms

ANSWERS TO TEST

13. Evaluated to satisfaction of instructor
14. Evaluated to satisfaction of instructor
15. Evaluated to satisfaction of instructor
16. Evaluated to satisfaction of instructor
17. Evaluated to satisfaction of instructor
18. Evaluated to satisfaction of instructor
19. Evaluated to satisfaction of instructor
20. Evaluated to satisfaction of instructor
21. Performance skills evaluated to satisfaction of instructor

OSCILLOSCOPE
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to demonstrate the ability to set up an oscilloscope for operation, adjust oscilloscope controls for stable display, measure frequency, and measure voltage. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score or 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with using the oscilloscope to their correct definitions.
2. List main uses of an oscilloscope.
3. Label main voltage waveforms.
4. Identify AC and DC voltage waveforms.
5. Match basic controls of a dual-trace oscilloscope to their correct functions.
6. Label AC sine wave components.
7. Identify rectangular wave components.
8. Convert units of time to their decimal equivalents.
9. Convert units of voltage to their decimal equivalents.
10. Convert units of frequency to their decimal equivalents.
11. Calculate effective or root-mean-square voltage from oscilloscope sine wave dimensions.
12. Calculate time and frequency from oscilloscope waveform dimensions.
13. Determine phase relationships of AC signals.
14. Arrange in order steps for calibrating an oscilloscope probe.
15. Demonstrate the ability to
    a. Set up an oscilloscope for operation.
    b. Adjust oscilloscope controls for a stable waveform display.

OBJECTIVE SHEET

c. Measure frequency using the oscilloscope.

d. Measure AC voltage using the oscilloscope.

e. Measure DC voltage using the oscilloscope.

f. Determine phase relationship of AC signals using the oscilloscope.

g. Calibrate an oscilloscope probe.

OSCILLOSCOPE
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Demonstrate distortion, noise, and instability by setting up circuits and signal generators.

   H. Give test.

II. Instructional materials

   A. Objective sheet

   B. Information sheet

   C Transparency masters

      1. TM #1--Typical Dual-Trace, Single-Time-Base Oscilloscope

      2. TM #2--Basic Cathode-Ray Tube

      3. TM #3--Simplified Block-Diagram Oscilloscope

      4. TM #4--CRT Signal Trace

      5. TM #5--Phase Relationships of AC Signals

      6. TM #6--Lissajous Phase Patterns

      7. TM #7--Lissajous Phase Patterns (Continued)

   D. Assignment sheets

      1. Assignment Sheet #1--Convert Units of Time to Their Decimal Equivalents

      2. Assignment Sheet #2--Convert Units of Voltage to Their Decimal Equivalents

SUGGESTED ACTIVITIES

3. Assignment Sheet #3--Convert Units of Frequency to Their Decimal Equivalents

4. Assignment Sheet #4--Calculate Effective or Root-Mean-Square Voltage from Sine Wave Dimensions

5. Assignment Sheet #5--Calculate Time and Frequency from Waveform Dimensions

6. Assignment Sheet #6--Determine Phase Relationships of AC Signals

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1--Set Up an Oscilloscope for Operation

2. Job Sheet #2--Adjust Oscilloscope Controls for a Stable Waveform Display

3. Job Sheet #3--Measure Frequency Using the Oscilloscope

4. Job Sheet #4--Measure AC Voltage Using the Oscilloscope

5. Job Sheet #5--Measure DC Voltage Using the Oscilloscope

6. Job Sheet #6--Determine Phase Relationships of AC Signals Using the Oscilloscope

7. Job Sheet #7--Calibrate an Oscilloscope Probe

G. Test

H. Answers to test

III. Unit reference--Cooper, William David. *Electronic Instrumentation and Measurement Techniques.* Englewood Cliffs, N.J.: Prentice-Hall, 1970.

OSCILLOSCOPE
UNIT II

INFORMATION SHEET

I. Terms and definitions

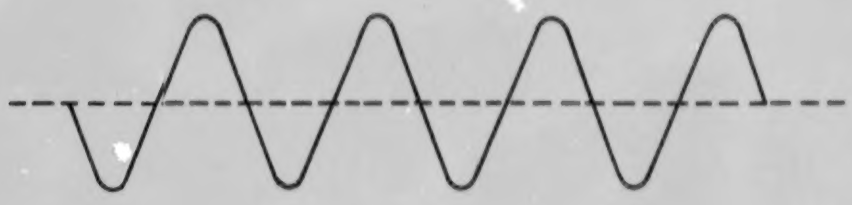
A. Oscilloscope--Instrument that produces an image of voltage on a cathode-ray tube screen

B. Voltage waveform--Visual representation of voltage showing changes to within fractions of a second

C. Sine wave--Waveform having smooth and rounded peaks, uniformly spaced and proportioned (Figure 1)

EXAMPLE:

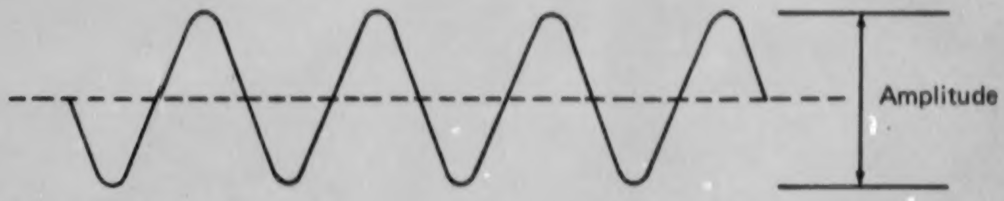
FIGURE 1



D. Amplitude--Height of a waveform (Figure 2)

EXAMPLE:

FIGURE 2

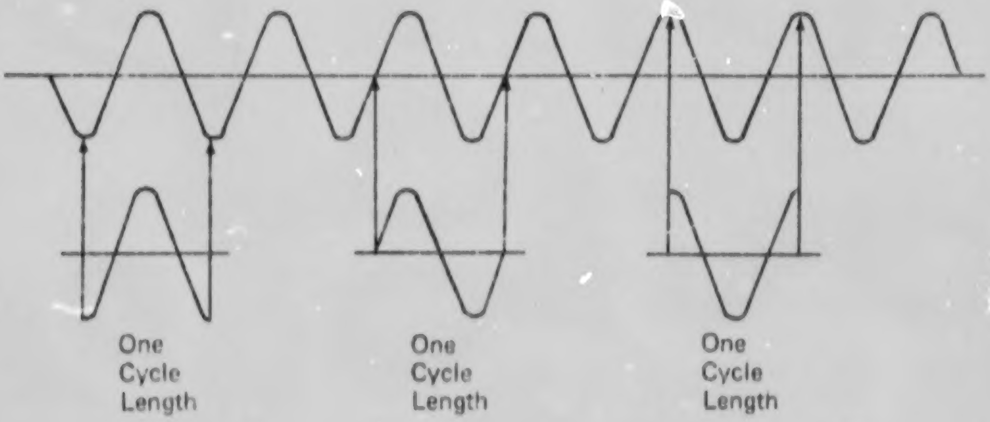


E. Cycle length--Waveform section that is continuously repeated (Figure 3)

(NOTE: On a uniform wave, one cycle can be measured from any point to the next identical point.)

EXAMPLE:

FIGURE 3



F. Vernier--Variable control for fine adjustment

G. Sweep--Action of the image-producing beam as it flashes across oscilloscope screen

(NOTE: Sweep also may be referred to as *trace*.)

H. Probe--Device connecting oscilloscope to circuits to be analyzed

I. Effective voltage--Measurement of effectiveness of waveform in supplying power

(NOTE: Effective voltage also may be referred to as *root-mean-square* or *rms voltage*.)

J. Graticule--Grid lines on face of oscilloscope screen

K. Trigger--Device used to initiate the sweep or trace, usually at a rate of thousands of times each second or more

II. Main uses of an oscilloscope

A. To view waveform characteristics

B. To measure frequency

INFORMATION SHEET

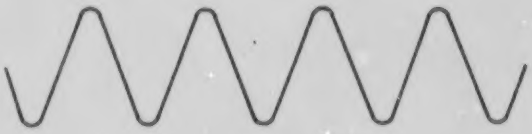
C. To measure voltage

D. To compare timing between two different signals

III. Main voltage waveforms (Figures 4-6)

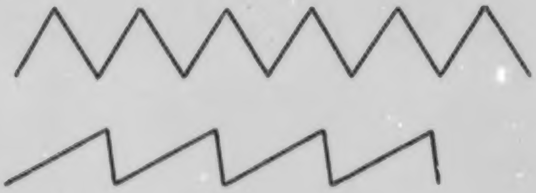
A. Sine waves

FIGURE 4



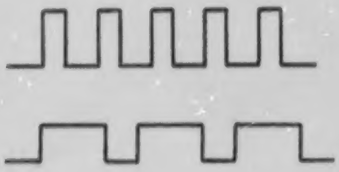
B. Triangular or sawtooth waves

FIGURE 5



C. Rectangular or square waves

FIGURE 6



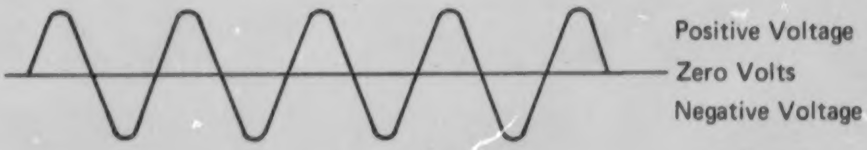
IV. AC and DC voltage waveforms (Figures 7 and 8)

A. AC voltages

(NOTE: AC voltages alternate between positive and negative values.)

1. Sine wave

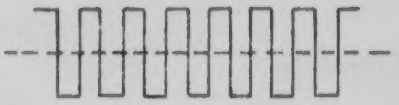
FIGURE 7


Positive Voltage
Zero Volts
Negative Voltage

INFORMATION SHEET

2. Rectangular wave

FIGURE 8



B. DC voltages

(NOTE: DC voltages always remain either positive or negative.)

1. Positive voltage

______________________________ + VDC

______________________________ 0 Reference Level

2. Negative voltage

______________________________ 0 Reference Level

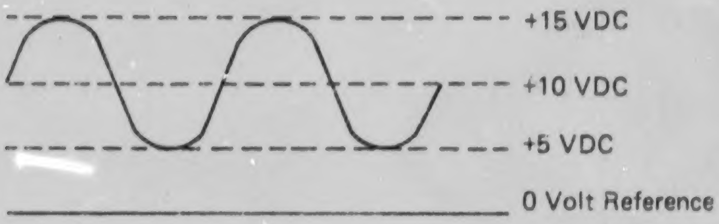
______________________________ -VDC

C. AC voltages riding a DC level (Figures 9 and 10)

(NOTE: The center reference point of an AC sine wave can be referenced at any level.)

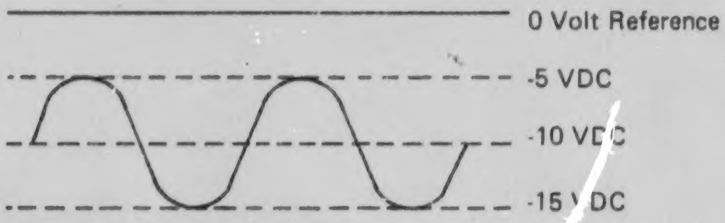
1. AC sine wave riding a positive 10 VDC level

FIGURE 9


+15 VDC
+10 VDC
+5 VDC
0 Volt Reference

2. AC sine wave riding a negative 10 VDC level

FIGURE 10


0 Volt Reference
-5 VDC
-10 VDC
-15 VDC

INFORMATION SHEET

V. Basic controls and functions of a dual-trace oscilloscope (Transparency #1)

A. Power switch--Turns oscilloscope on and off

B. Scale illumination--Lights the screen and graticule

(NOTE: Scale illumination is usually variable. On newer models of oscilloscopes, the power switch and scale illumination are usually one control.)

C. Focus--Adjusts image clarity of electrons being pulled forward by the accelerating anode by concentrating into a fine beam both the focusing and the accelerated anode (Transparencies #2 and #3)

D. Cal--Provides a rectangular calibration signal to check accuracy of the oscilloscope

(NOTE: *Cal* is the abbreviation for calibration.)

E. Intensity--Adjusts image brightness by limiting the number of electrons allowed to reach the face of the cathode-ray tube

F. Sweep mode--Selects which channel will be displayed on screen

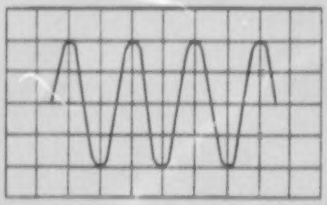
G. Horizontal position--Moves image to the right or left across screen by changing the polarity of the voltage to the horizontal deflection plates (Transparencies #2 and #3)

H. Sweep time/cm--Selects horizontal sweep rate by expanding and compressing the sine wave in the horizontal direction (Figures 11-13)

(NOTE: Vernier must be in calibrate position if frequency measurements are to be made.)

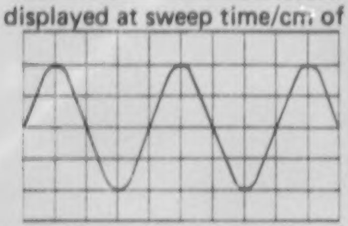
EXAMPLES:

FIGURE 11



Sine wave displayed at sweep time/cm of 10 milliseconds

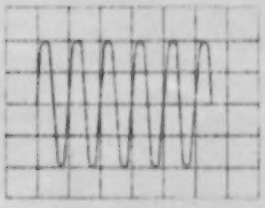
FIGURE 12



Same sine wave displayed at sweep time/cm of 5 milliseconds

INFORMATION SHEET

FIGURE 13



Same sine wave displayed at sweep time/cm of 20 milliseconds

I. EXT HORIZ INPUT--Provides control of sweep by an external voltage waveform

(NOTE: EXT HORIZ INPUT is the abbreviation for *external horizontal input.*)

J. Trigger source--Selects signal that must initiate or trigger sweep

EXAMPLES: Channel A, Channel B, internal, or external

K. Trigger slope--Selects part of triggering waveform, positive or negative, that initiates sweep

L. Trigger level--Selects voltage level of triggering waveform that initiates sweep

M. Trigger channel--Selects which channel's voltage waveform will initiate sweep if trigger source is selected for "INT" or internal

N. EXT TRIG--Provides connection of external voltage waveform to trigger sweep

(NOTE: EXT TRIG is the abbreviation for *external trigger input.*)

O. VERT POS--Positions image up or down on screen by changing the polarity of voltage applied to the vertical deflection plates (Transparencies #2, #3, and #4)

(NOTE: VERT POS is the abbreviation for *vertical position.*)

P. Coupling--Selects between DC or AC connections

(NOTE: DC steady-state voltages cannot be measured if an AC connection is selected.)

Q. CH A Input and CH B Input--Provides connection of cable and probe through which voltage waveforms will be monitored

(NOTE: *CH A* and *CH B* stand for Channel A and Channel B inputs, respectively, and are usually identical.)

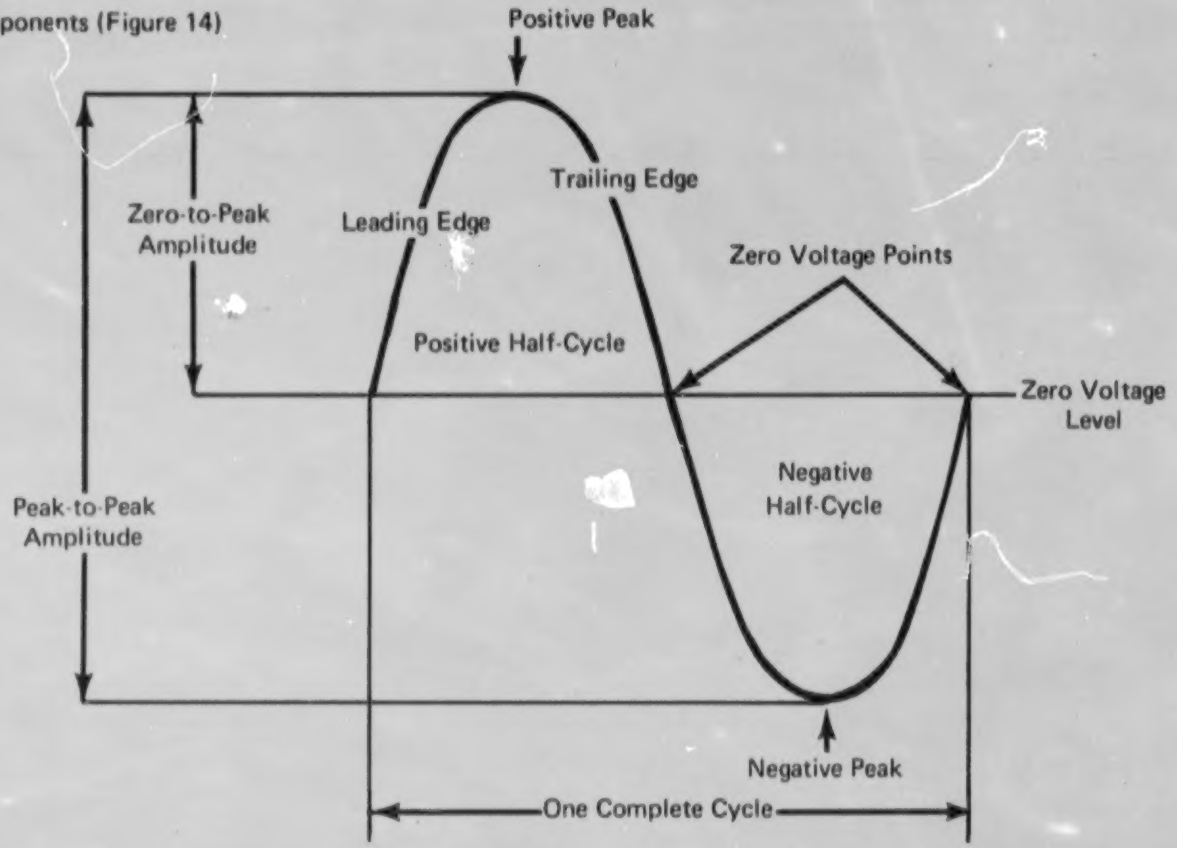
INFORMATION SHEET

R. Volts/cm--Selects vertical display amplitude

(NOTE: Vernier must be in calibrate position if voltage measurements are to be made; appears to expand and compress waveform in the vertical direction.)

VI. AC sine wave components (Figure 14)

FIGURE 14


Positive Peak
Trailing Edge
Zero-to-Peak Amplitude
Leading Edge
Zero Voltage Points
Positive Half-Cycle
Zero Voltage Level
Negative Half-Cycle
Peak-to-Peak Amplitude
Negative Peak
One Complete Cycle

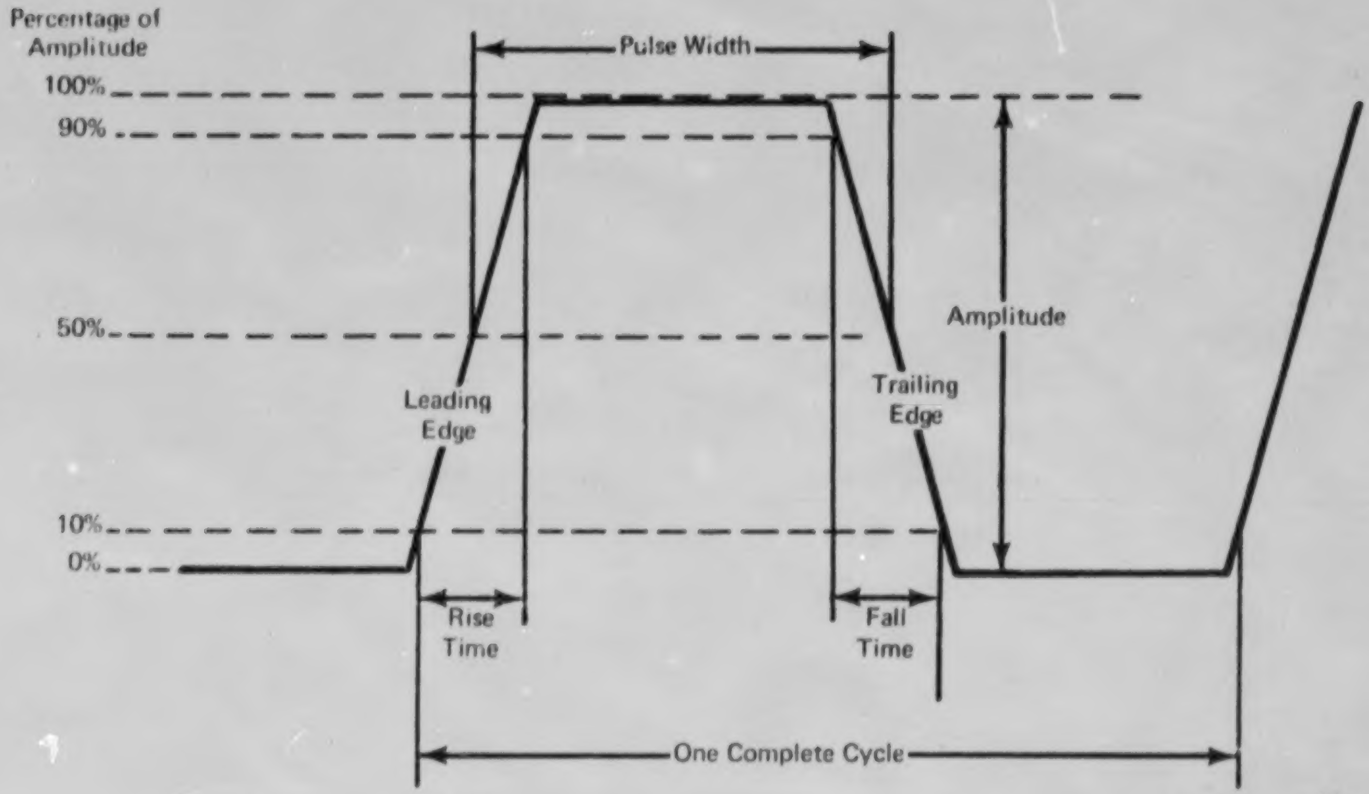
521

INFORMATION SHEET

VII. Rectangular wave components (Figure 15)

(NOTE: Measurements are according to percent of amplitude.)

FIGURE 15


Percentage of Amplitude
100%
90%
50%
10%
0%
Pulse Width
Amplitude
Leading Edge
Trailing Edge
Rise Time
Fall Time
One Complete Cycle

INFORMATION SHEET

VIII. Converting units of time to their decimal equivalents (Assignment Sheet #1)

A. Milliseconds (ms)

(NOTE: This expression or abbreviation stands for one one-thousandth of a second or 1×10^{-3}.)

1. To convert milliseconds to seconds, delete the "m" and move the decimal point three places to the left

EXAMPLES: 100 ms = .1 s
4 ms = .004 s
.2 ms = .0002 s

2. To convert seconds to milliseconds, move the decimal point three places to the right and include the "m"

EXAMPLES: .0004 s = .4 ms
.82 s = 820 ms
6 s = 6000 ms

B. Microseconds (μs)

(NOTE: This expression or abbreviation stands for one one-millionth of a second or 1×10^{-6} seconds. This indicates that the decimal has been moved six places to the right.)

1. To convert microseconds to seconds, delete the "μ" and move the decimal point six places to the left

EXAMPLES: 10 μs = .00001 s
2.7 μs = .0000027 s
400 μs = .0004 s

2. To convert seconds to microseconds, move the decimal point six places to the right and include the "μ"

EXAMPLES: .00078 s = 780 μs
.001283 s = 1283 μs
.0000004 s = .4 μs

IX. Converting units of voltage to their decimal equivalents (Assignment Sheet #2)

A. To convert millivolts (mV) to volts, move the decimal point three places to the left and delete the "m"

(NOTE: A millivolt is equal to one one-thousandth of a volt or 1×10^{-3}.)

EXAMPLES: 50 mV = .05 V
130 mV = .13 V
2 mV = .002 V

INFORMATION SHEET

B. To convert volts to millivolts, move the decimal point three places to the right and include the "m"

EXAMPLES: .008 V = 8 mV
.170 V = 170 mV
.020 V = 20 mV

X. Converting units of frequency to their decimal equivalents (Assignment Sheet #3)

A. Hertz (**Hz**)--Equivalent to "cycles per second"

EXAMPLES: 60 Hz = 60 cps
1,000 Hz = 1,000 cps
200 Hz = 200 cps

B. Kilohertz (**kHz**)

(NOTE: This expression or abbreviation stands for one thousand cycles per second or 1×10^3. This indicates that the decimal has been moved three places to the left.)

1. To convert kilohertz to hertz, move the decimal point three places to the right and delete the "k"

EXAMPLES: 4 kHz = 4,000 Hz
.75 kHz = 750 Hz
520 kHz = 520,000 Hz

2. To convert hertz to kilohertz, move the decimal point three places to the left and include the "k"

EXAMPLES: 156,500 Hz = 156.5 kHz
78,000 Hz = 78 kHz
500 Hz = .5 kHz

C. Megahertz (**MHz**)

(NOTE: This expression or abbreviation stands for one million cycles per second or 1×10^6 cycles per second. This indicates that the decimal has been moved six places to the left.)

1. To convert megahertz to hertz, move the decimal point six places to the right and delete the "M"

EXAMPLES: 4 MHz = 4,000,000 Hz
.42 MHz = 420,000 Hz
21 MHz = 21,000,000 Hz

INFORMATION SHEET

2. To convert hertz to megahertz, move the decimal point six places to the left and include the "M"

EXAMPLES: 620,000 Hz = .62 MHz
58,000,000 Hz = 58 MHz
7,000,000 Hz = 7 MHz

(NOTE: To convert kilohertz to megahertz or megahertz to kilohertz, first convert to hertz and then follow the conversion rules for hertz, kilohertz, or megahertz.)

EXAMPLE: 7500 kHz = ? MHz
7500 kHz = $7{,}500{,}\overline{000}$ Hz
7,500,000 Hz = 7.5 MHz
Therefore: 7500 kHz = 7.5 MHz

XI. Calculating effective or root-mean-square voltage from oscilloscope sine wave dimensions (Assignment Sheet #4)

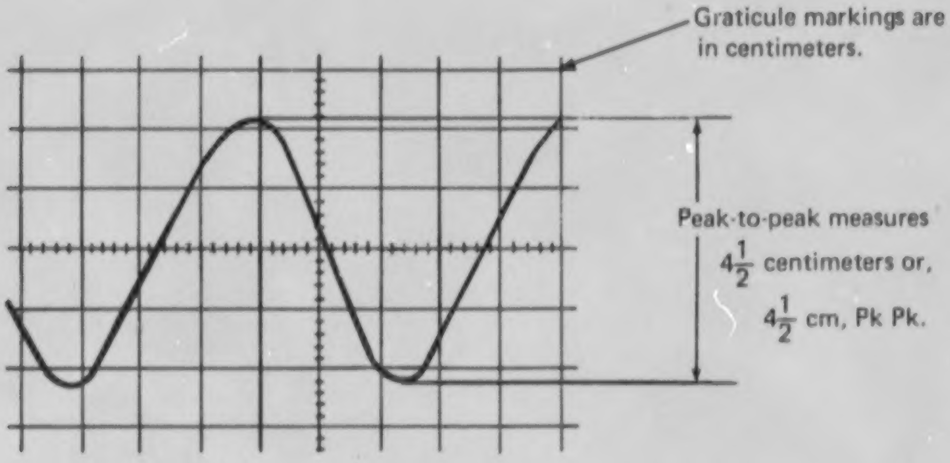
A. Check the VOLTS/cm vernier to make certain that it is in the calibrate position

B. Measure the sine wave peak-to-peak distance with the graticule on the screen; position the wave with the vertical position control, if necessary (Figure 16)

(NOTE: Peak-to-peak is abbreviated *Pk-Pk*.)

EXAMPLE:

FIGURE 16


Graticule markings are in centimeters.
Peak-to-peak measures $4\frac{1}{2}$ centimeters or, $4\frac{1}{2}$ cm, Pk Pk.

INFORMATION SHEET

C. Check the VOLTS/cm selector position; multiply that value by peak-to-peak graticule measurement to give peak-to-peak voltage

EXAMPLE 1: Graticule measurement = $4\frac{1}{2}$ cm

Volts/cm selector = 2 volts/cm

Peak-to-peak voltage = $2 \times 4\frac{1}{2}$

= 9 volts, Pk-Pk

EXAMPLE 2: Graticule measurement = 6 cm

Volts/cm selector = .1 volts/cm

Peak-to-peak voltage = $.1 \times 6$

= .6 volts, Pk-Pk

D. Check oscilloscope probe

1. Probe directly passing the voltage wave will be marked "1X" and has no effect on the calculations
2. Probe attenuating that voltage wave will be marked "10X," indicating voltage reading should be multiplied by ten

EXAMPLE: Graticule measurement = $2\frac{1}{4}$ cm

Volts/cm selector = 10 volts/cm

Probe = 10X

Peak-to-peak voltage = $2\frac{1}{4} \times 10 \times 10$

= 225 volts, Pk-Pk

E. Effective voltage is .707 times one-half the peak-to-peak voltage

EXAMPLE 1: Graticule measurement = $6\frac{1}{5}$ cm, Pk-Pk

Volts/cm selector = 5 volts/cm

Probe = 10X

Peak-to-peak voltage = $6\frac{1}{5} \times 5 \times 10$

= 310 volts, Pk-Pk

Effective voltage = $310 \times \frac{1}{2} \times .707$

= 109.6 volts, rms

(NOTE: Ordinary receptacle voltage of about 110 volts is 310 volts, Pk-Pk.)

INFORMATION SHEET

EXAMPLE 2: Graticule measurement = $3\frac{2}{5}$ cm, Pk-Pk

Volts/cm = 20 volts/cm

Probe = 1X

Peak-to-peak voltage = $3\frac{2}{5} \times 20 \times 1$

= 68 volts, Pk-Pk

Effective voltage = $68 \times \frac{1}{2} \times .707$

= 24 volts, rms

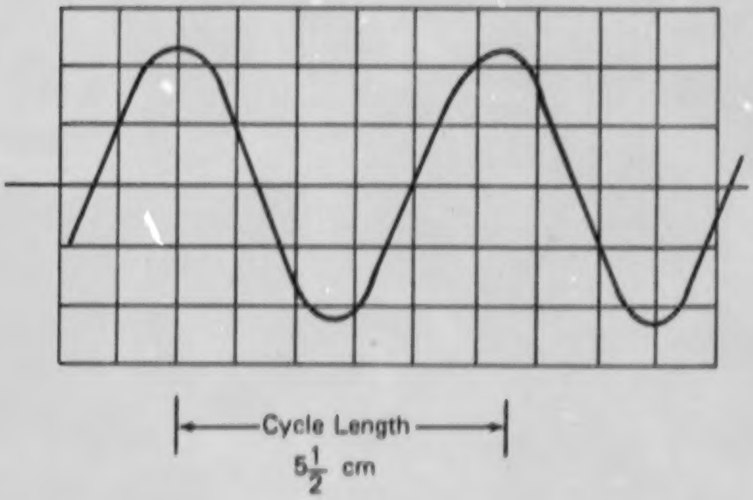
XII. Calculating time and frequency from oscilloscope waveform dimensions (Assignment Sheet #5)

A. Check the SWEEP vernier to make sure that it is in the calibrate position

B. Measure cycle length distance with the graticule on the screen; position wave with horizontal position control, if necessary (Figure 17)

EXAMPLE:

FIGURE 17



INFORMATION SHEET

C. Check the sweep time/cm position; multiply that value by the graticule measurement to give the time per cycle

EXAMPLE: Graticule measurement = $5\frac{1}{2}$ cm

Sweep time/cm = 5 ms/cm

Time per cycle = $5\frac{1}{2}$ cm x 5 ms/cm

= 27.5 ms

= .0275 s

D. Divide the time per cycle into 1 to get the cycles per time or the frequency

(NOTE: Use the formula $f = \frac{1}{T}$.)

EXAMPLE 1: Time per cycle = .0275 s

$\frac{1}{.0275}$ = 36.36 cps

= 36.36 Hz

EXAMPLE 2: Graticule measurement = 4 cm

Sweep time/cm = 10 μs/cm

Time per cycle = 4 cm x 10 μs/cm

= 40 μS

= .00004 s

Frequency = $\frac{1}{.00004}$

= 25,000 cps

= 25,000 Hz

= 25 kHz

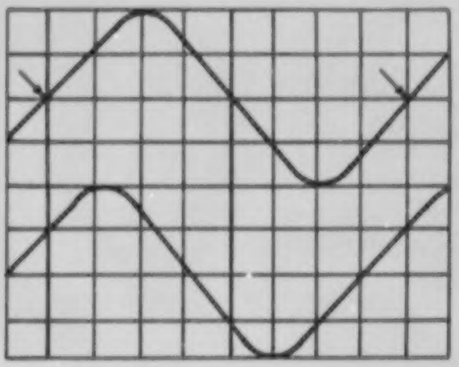
INFORMATION SHEET

XIII. Methods of determining phase relationships of AC signals (Assignment Sheet #6)

A. Comparing two sine waves displayed on a dual trace oscilloscope simultaneously, with one sine wave on each trace (Transparency #5; Figure 18)

(NOTE: This is the most accurate method to determine phase relationships.)

FIGURE 18



1. Apply the sine wave to the input of CH A or CH B of a dual-trace oscilloscope

2. Adjust the sweep time/cm and sweep time vernier oscilloscope controls so one cycle covers 8 cm

   (NOTE: One full cycle [8 cm] now equals 360°; one half cycle [4 cm] equals 180°; one quarter cycle [2 cm] equals 90°; one eighth cycle [1 cm] equals 45°.)

3. Apply the second sine wave to the remaining channel of the oscilloscope

4. Compare the same point of each sine wave for the separation distance

   EXAMPLE: The positive peak of each sine wave in the above presentation is 1 cm apart

   Phase difference = Number of cm x 45°/cm

   = 1 cm x 45°/cm

   = 45°

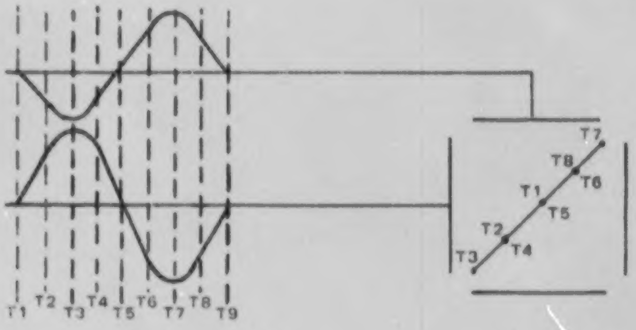
INFORMATION SHEET

B. Comparing two sine waves on a dual trace oscilloscope by applying one signal to the vertical input and the second signal to the horizontal input (Transparency #6; Figure 19)

(NOTE: By applying a signal to both the horizontal and vertical plates of the cathode-ray tube, the signal causes the electron beam to move accordingly.)

EXAMPLE:

FIGURE 19



1. At time one (T1), both signals are zero; thus, the electron beam is centered both vertically and horizontally
2. At time two (T2), the vertical signal is going positive, which will attract the electron beam, while the horizontal signal is going negative, which will repel the electron beam an equal amount
3. At time three (T3), the vertical signal is maximum positive, applying even greater attraction to the electron beam, while the horizontal signal is maximum negative, which causes equal but greater repulsion of the electron beam
4. At time four (T4), the vertical signal is again at a less positive potential, causing less attraction to the electron beam, while the horizontal signal causes less repulsion, allowing the electron beam to return toward the center position
5. At time five (T5), both vertical and horizontal signals are at a zero potential, causing neither attraction or repulsion, thus allowing the electron beam to return to the center position
6. At time six (T6), the vertical signal is going negative, causing a repulsion of the electron beam, while the horizontal signal is going positive, causing an attraction of the electron beam
7. At time seven (T7), the vertical signal is maximum negative, causing maximum repulsion of the electron beam, while the horizontal signal is maximum positive, causing maximum attraction of the electron beam

INFORMATION SHEET

8. At time eight (T8), the vertical signal is less negative, causing less repulsion of the electron beam, while the horizontal signal is less positive, causing less attraction of the electron beam

9. At time nine (T9), the signals are again at zero, or time one; thus the electron beam is again centered on the cathode-ray tube

XIV. Steps for calibrating an oscilloscope probe

A. Turn on oscilloscope

B. Adjust oscilloscope for steady trace

C. Connect oscilloscope probe to Channel A or B vertical input

D. Adjust the volts/cm control for a setting which will allow one peak-to-peak signal to be visible on the cathode-ray tube

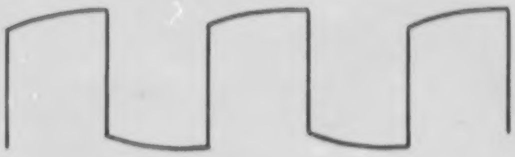
(NOTE: A more accurate adjustment can be made with a larger peak-to-peak signal.)

E. Insert test probe into calibration jack on oscilloscope

F. Check square wave signal for distortion (Figure 20)

EXAMPLE:

FIGURE 20



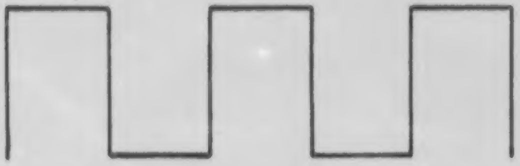
INFORMATION SHEET

G. Locate calibration adjust on oscilloscope probe

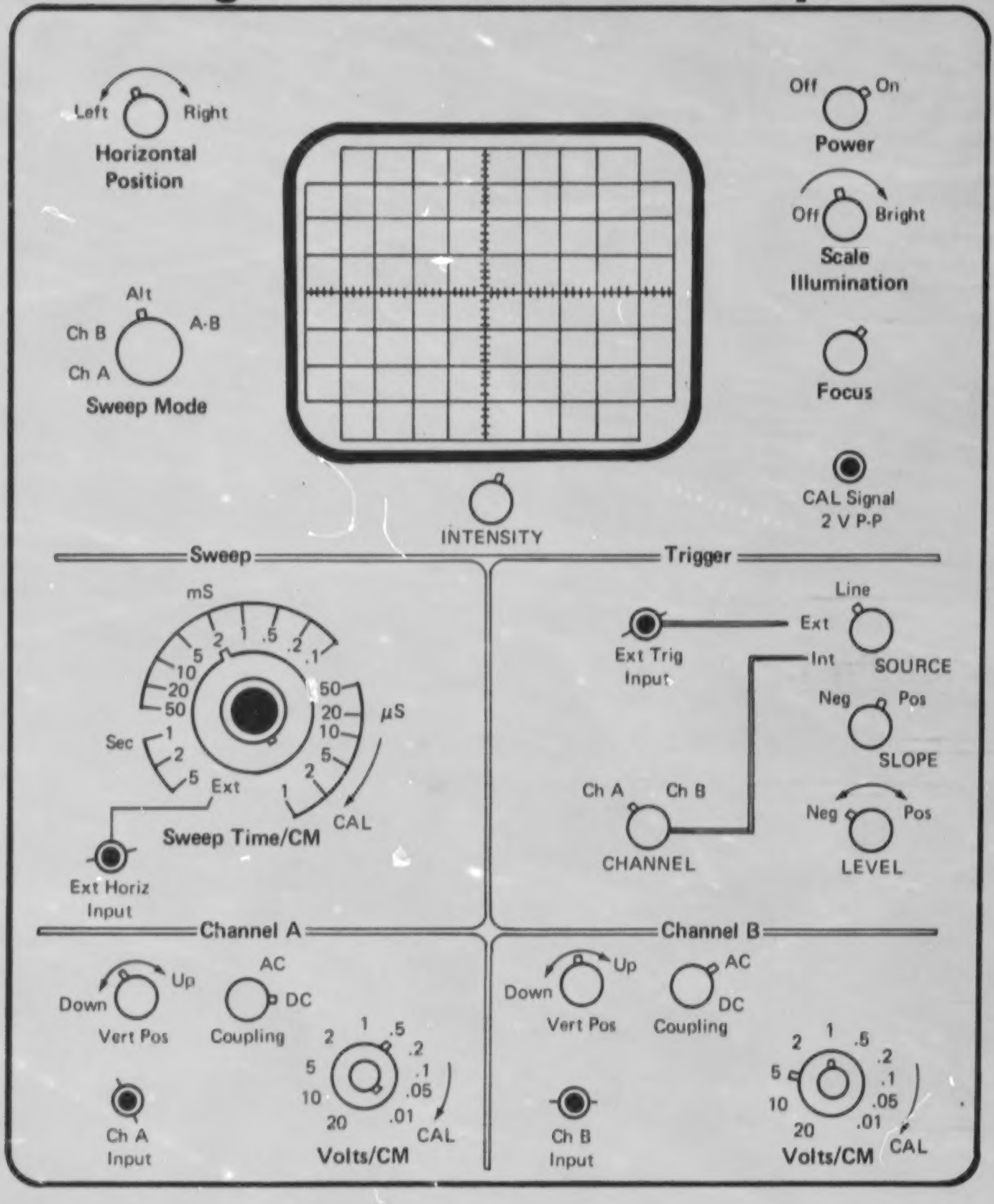
H. Adjust calibration adjust until square wave has no distortion (Figure 21)

EXAMPLE:

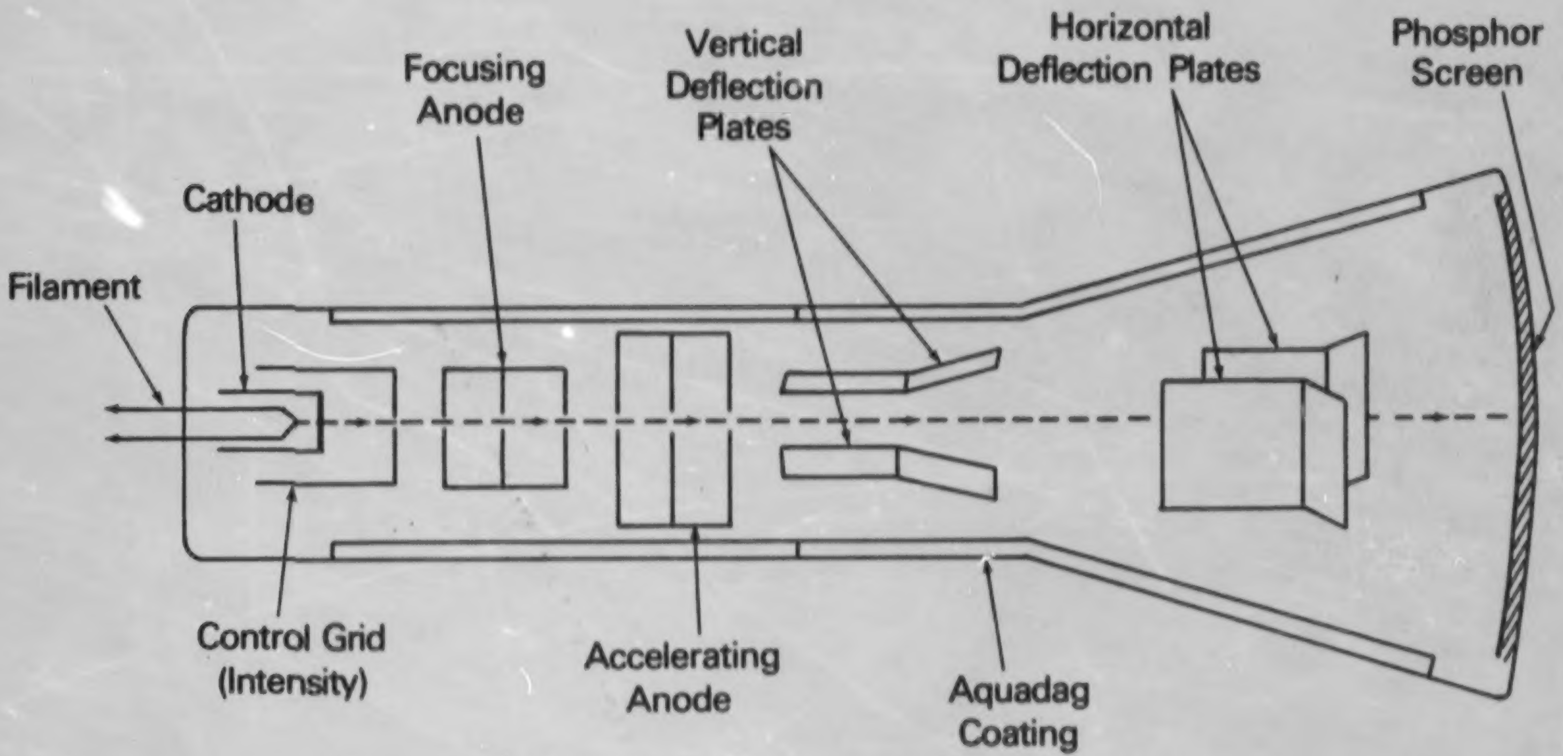
FIGURE 21



Typical Dual-Trace, Single-Time-Base Oscilloscope


Left
Right
Horizontal Position
Off
On
Power
Off
Bright
Scale Illumination
Alt
Ch B
A-B
Ch A
Sweep Mode
Focus
CAL Signal 2 V P-P
INTENSITY
Sweep
Trigger
mS
2
1
.5
.2
.1
5
10
20
50
50
20
10
5
2
1
μS
Sec
1
2
5
Ext
CAL
Sweep Time/CM
Ext Horiz Input
Line
Ext
Int
SOURCE
Ext Trig Input
Neg
Pos
SLOPE
Ch A
Ch B
CHANNEL
Neg
Pos
LEVEL
Channel A
Channel B
Down
Up
Vert Pos
AC
DC
Coupling
2
1
.5
.2
.1
.05
.01
5
10
20
CAL
Volts/CM
Ch A Input
Ch B Input

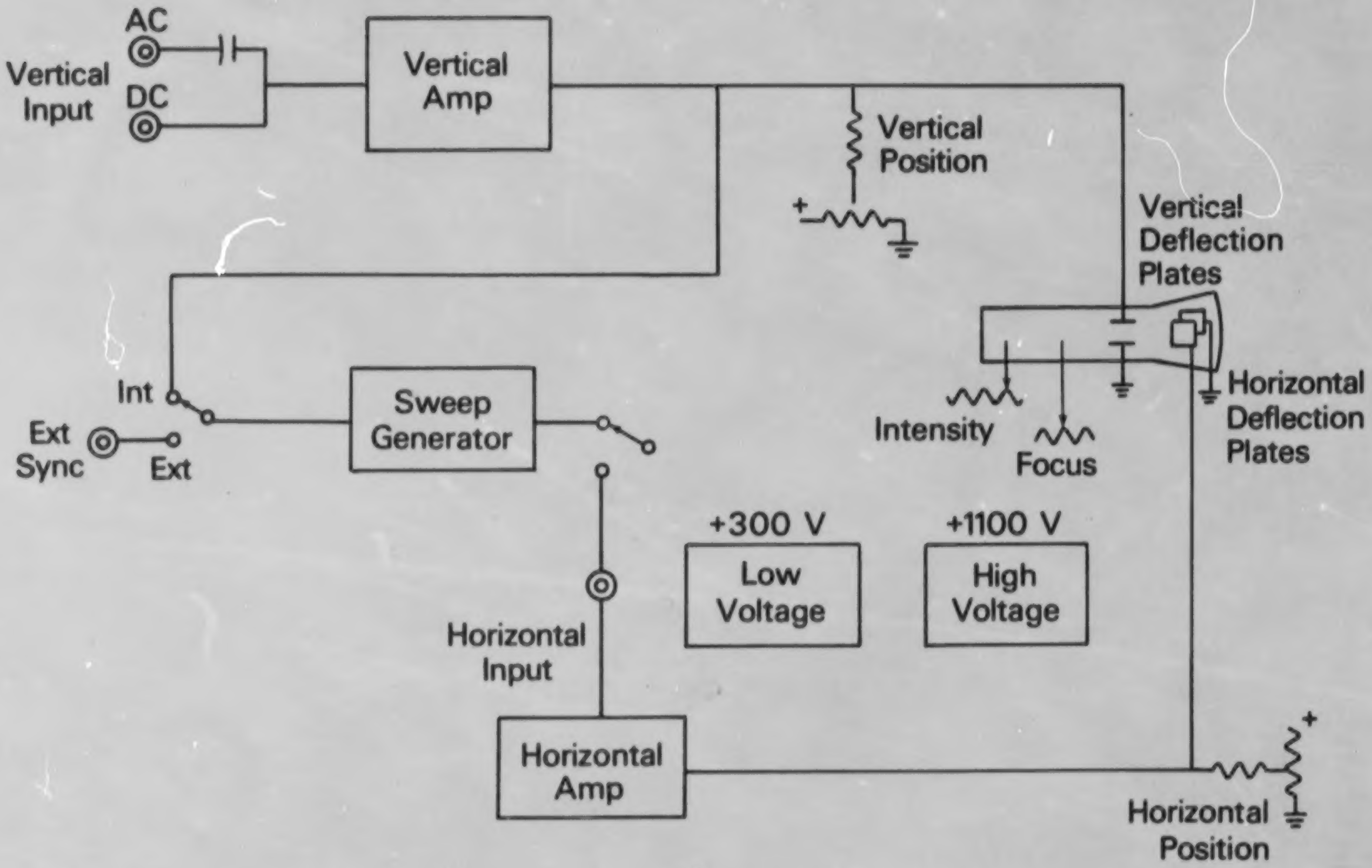
Basic Cathode-Ray Tube


Focusing Anode
Vertical Deflection Plates
Horizontal Deflection Plates
Phosphor Screen
Cathode
Filament
Control Grid (Intensity)
Accelerating Anode
Aquadag Coating

TM #2

IIEE - 107-D

Simplified Block-Diagram Oscilloscope

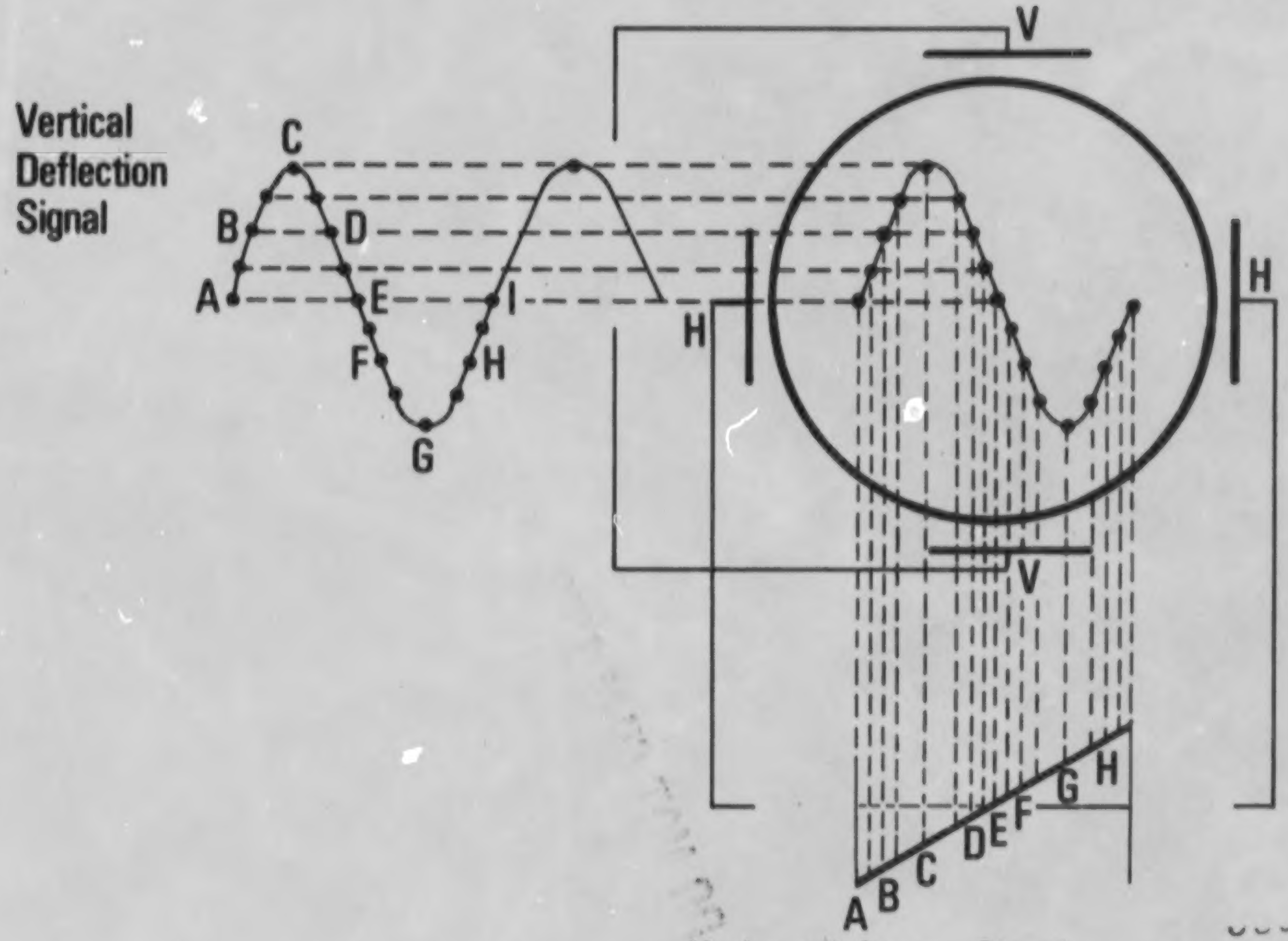


AC
Vertical Input
DC
Vertical Amp
Vertical Position
+
Vertical Deflection Plates
Int
Ext Sync
Ext
Sweep Generator
Intensity
Focus
Horizontal Deflection Plates
+300 V
Low Voltage
+1100 V
High Voltage
Horizontal Input
Horizontal Amp
+
Horizontal Position

TM #3

IIEE - 109-D

CRT Signal Trace

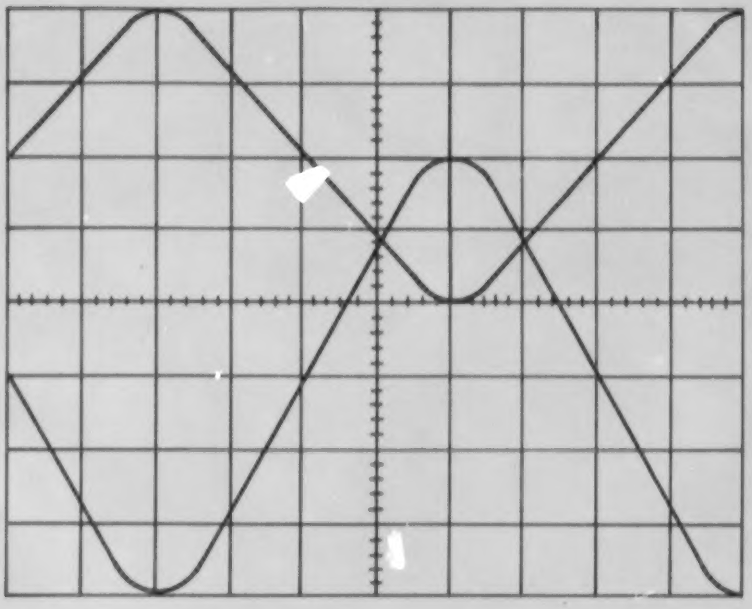

Vertical Deflection Signal
C
B
D
A
E
I
F
H
G
V
H
H
V
A
B
C
D
E
F
G
H

Horizontal Sweep Signal

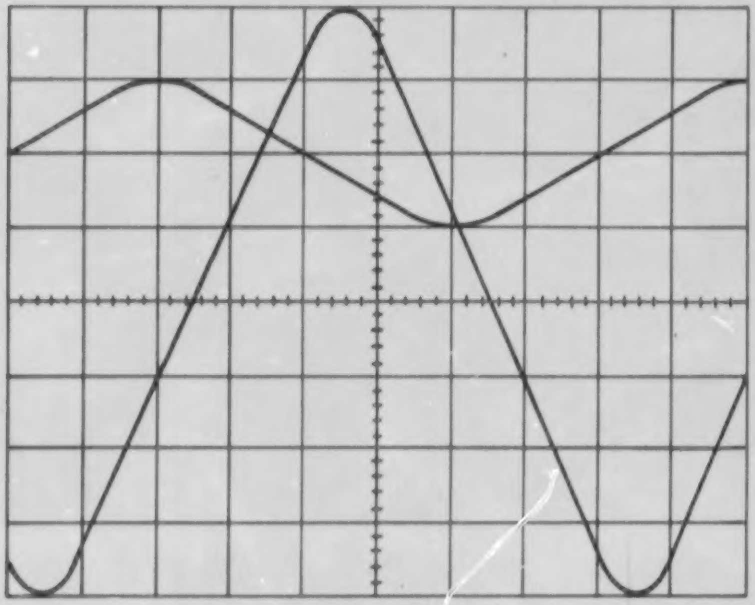
TM #4

IIEE-111-D

Phase Relationships of AC Signals

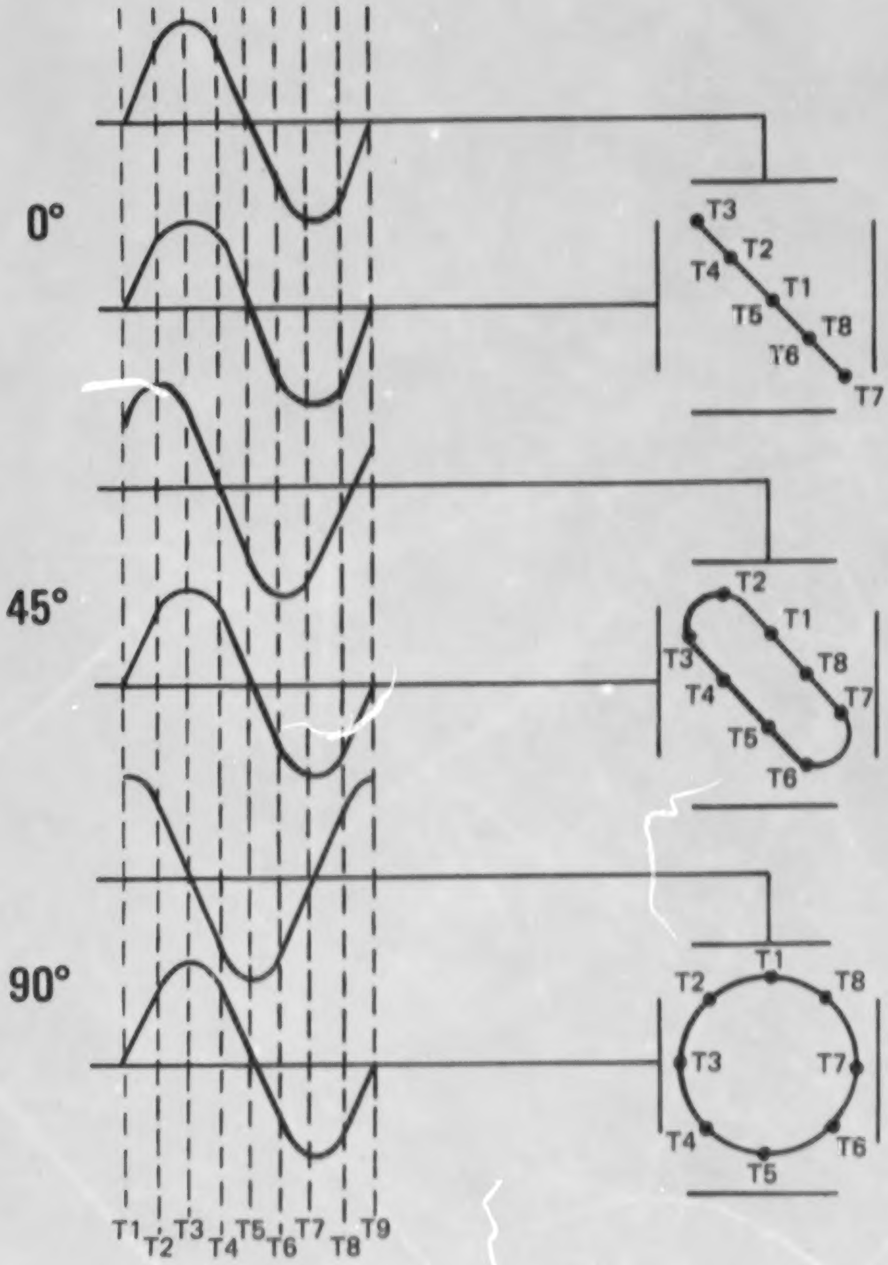


1 Cycle = 8 cm
1 cm = 45°
4 cm between Peaks
4 cm x 45° = 180°
or 180° Out of Phase



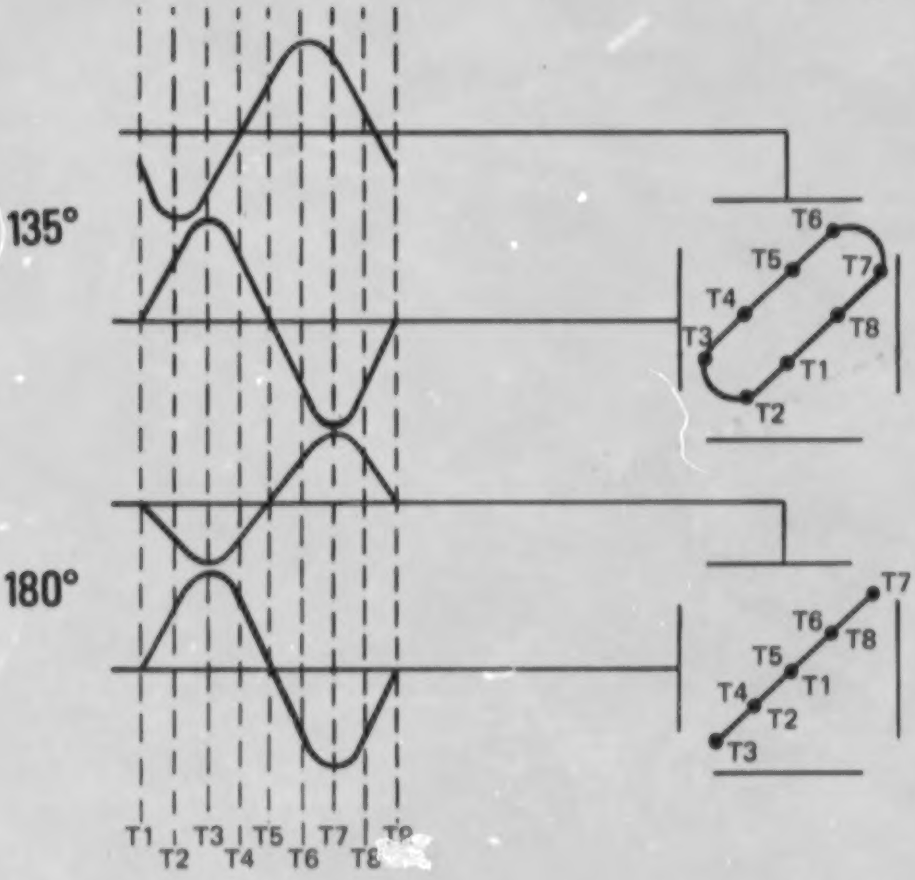
2.6 cm x 45° = 117°
or 117° Out of Phase

Lissajous Phase Patterns


0°
45°
90°
T1
T2
T3
T4
T5
T6
T7
T8
T9
T3
T2
T4
T1
T5
T8
T6
T7
T2
T1
T3
T8
T4
T7
T5
T6
T1
T2
T8
T3
T7
T4
T6
T5

Lissajous Phase Patterns

(Continued)


135°
180°
T1
T2
T3
T4
T5
T6
T7
T8
T9

OSCILLOSCOPE
UNIT II

ASSIGNMENT SHEET #1–CONVERT UNITS OF TIME TO THEIR DECIMAL EQUIVALENTS

NAME ______________________________ SCORE ______________

Using an oscilloscope to measure frequency requires converting expressions of time from one form to another. Convert the following expressions of time to the forms indicated.

1. 52,000 μs = ______________________________ s

2. 428 ms = ______________________________ s

3. .5287 s = ______________________________ ms

4. 75 s = ______________________________ ms

5. .006 s = ______________________________ μs

6. 283 μs = ______________________________ s

7. 87.2 ms = ______________________________ s

8. 276 μs = ______________________________ ms

9. 1.37 s = ______________________________ ms

10. 4.15 ms = ______________________________ μs

OSCILLOSCOPE
UNIT II

ASSIGNMENT SHEET #2--CONVERT UNITS OF VOLTAGE TO THEIR DECIMAL EQUIVALENTS

NAME ______________________________ SCORE ______________

To make voltage measurements with the oscilloscope, voltage expressions must be converted from one form to another. Convert the following voltage expressions to the forms indicated.

1. 500 mV = ______________________ V

2. .1 V = ______________________ mV

3. 1.287 V = ______________________ mV

4. 1,687 mV = ______________________ V

5. .002 V = ______________________ mV

6. 2,879 mV = ______________________ V

7. 73.51 V = ______________________ mV

8. 167,000 mV = ______________________ V

9. 2 V = ______________________ mV

10. 1,000 mV = ______________________ V

OSCILLOSCOPE
UNIT II

ASSIGNMENT SHEET #3--CONVERT UNITS OF FREQUENCY TO THEIR DECIMAL EQUIVALENTS

NAME ______________________________ SCORE ______________

To make frequency measurements with oscilloscopes, frequency expressions must be converted from one form to another. Convert the following frequency expressions to the forms indicated.

1. 40 cps = ______________________ Hz
2. 675 Hz = ______________________ cps
3. 675 Hz = ______________________ kHz
4. .794 kHz = ______________________ cps
5. 1.5 MHz = ______________________ Hz
6. 1,500 kHz = ______________________ MHz
7. 987,000 cps = ______________________ MHz
8. 3,790 Hz = ______________________ kHz
9. .02 MHz = ______________________ kHz
10. .007 kHz = ______________________ Hz

OSCILLOSCOPE
UNIT II

ASSIGNMENT SHEET #4--CALCULATE EFFECTIVE OR ROOT-MEAN-SQUARE VOLTAGE FROM SINE WAVE DIMENSIONS

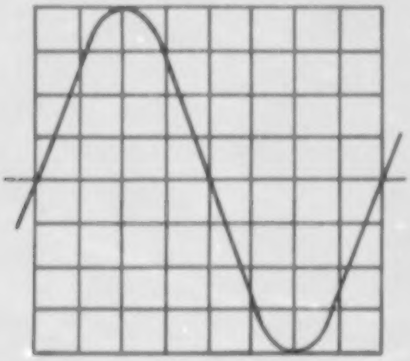
NAME ______________________________ SCORE ______________

Calculate the effective or root-mean-square (rms) voltage for each waveform in the problems below (Figures 22-25). Write the correct answers in the blanks.

1. Volts/cm set a 2

   Probe is 10X = ____________________ volts, rms

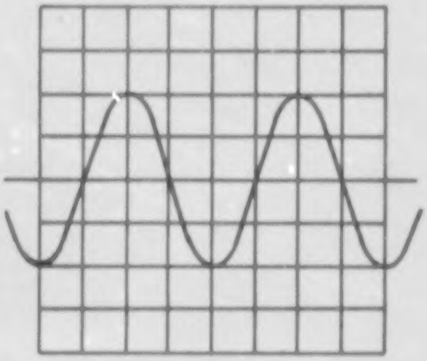
   FIGURE 22



2. Volts/cm set at .05

   Probe is 1X = ____________________ volts, rms

   FIGURE 23

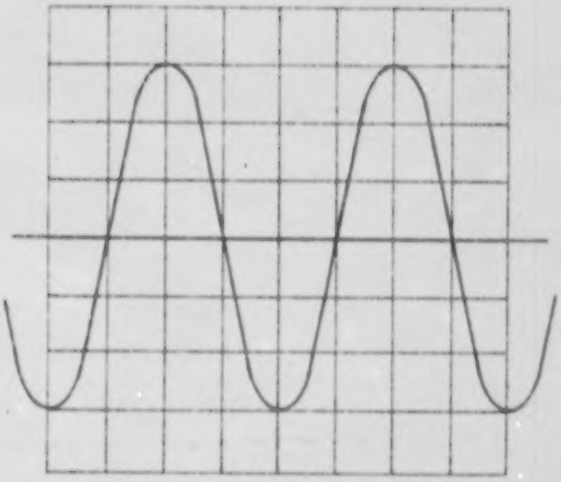


ASSIGNMENT SHEET #4

3. Volts/cm set at .5

Probe is 10X = ______________________________ volts, rms

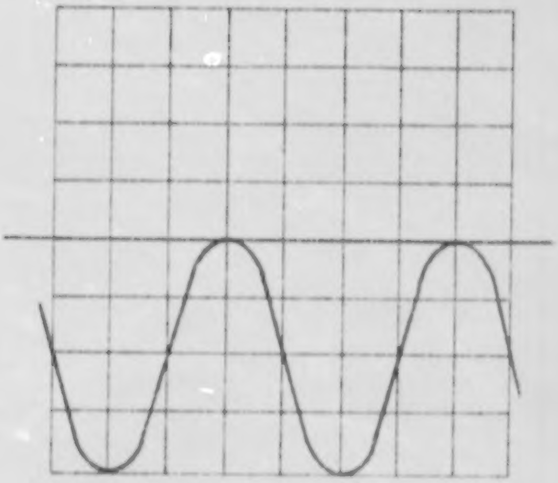
FIGURE 24



4. Volts/cm set at 20

Probe is 1X = ______________________________ volts, rms

FIGURE 25



OSCILLOSCOPE
UNIT II

ASSIGNMENT SHEET #5--CALCULATE TIME AND FREQUENCY FROM WAVEFORM DIMENSIONS

NAME ______________________________ SCORE ________________

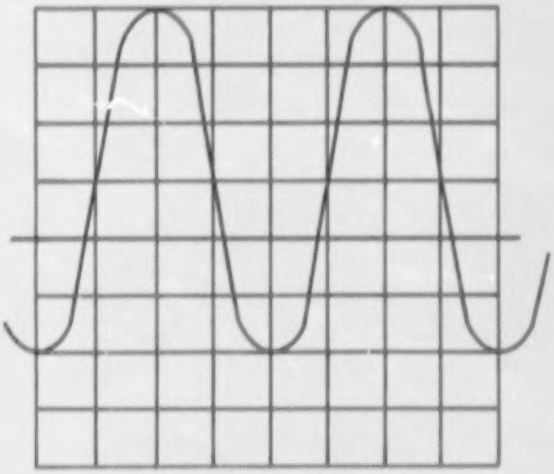
Calculate the time and frequency for each waveform in the problems below (Figures 26-29). Write the correct answers in the blanks.

1. Time/cm set at 2 μs/cm

________________ s

________________ MHz

FIGURE 26

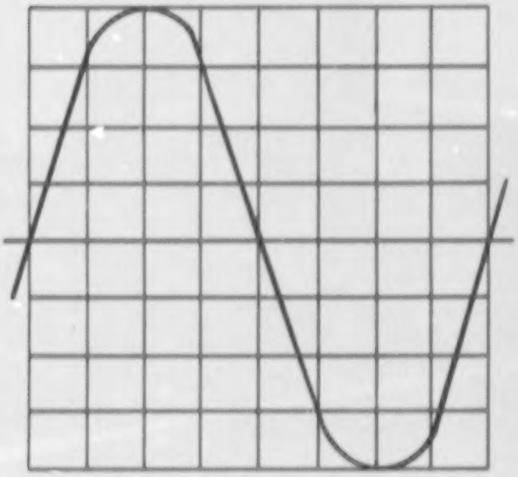


2. Time/cm set at 1 ms/cm

________________ s

________________ kHz

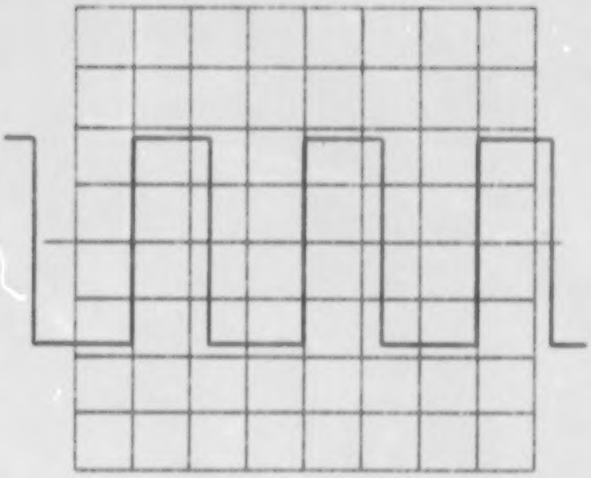
FIGURE 27



ASSIGNMENT SHEET #5

3. Time/cm set at 1 s/cm

FIGURE 28

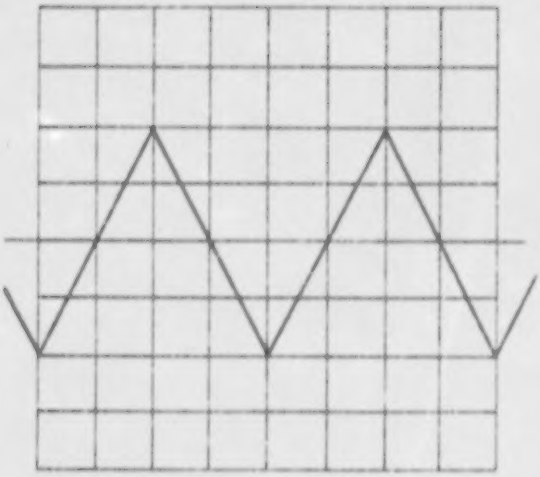


__________________ s

__________________ Hz

4. Time/cm set at .2 ms/cm

FIGURE 29



__________________ s

__________________ kHz

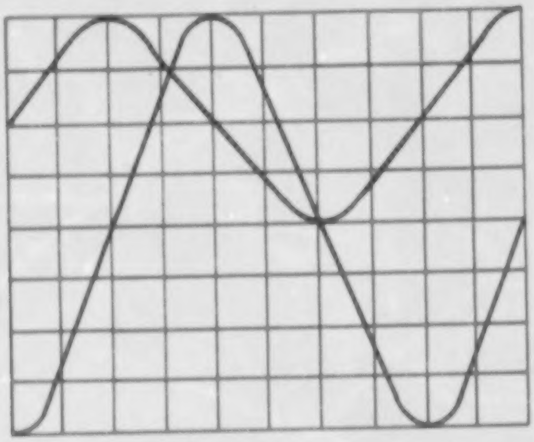
OSCILLOSCOPE
UNIT II

ASSIGNMENT SHEET #6–DETERMINE PHASE RELATIONSHIPS OF AC SIGNALS

NAME ______________________________ SCORE ______________

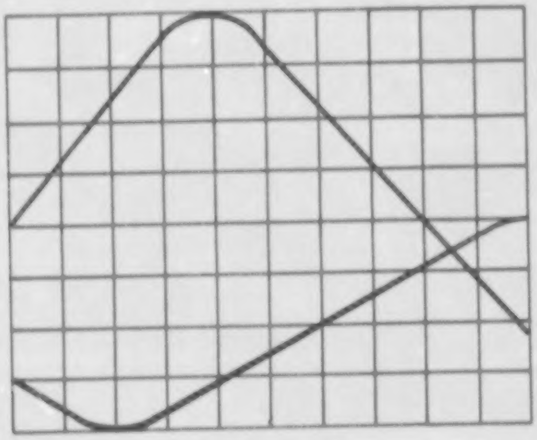
Calculate the phase relationships of the oscilloscope displays below (Figures 30-35). Write the correct answers in the blanks below each display.

FIGURE 30



1. ______________________________ degrees out of phase

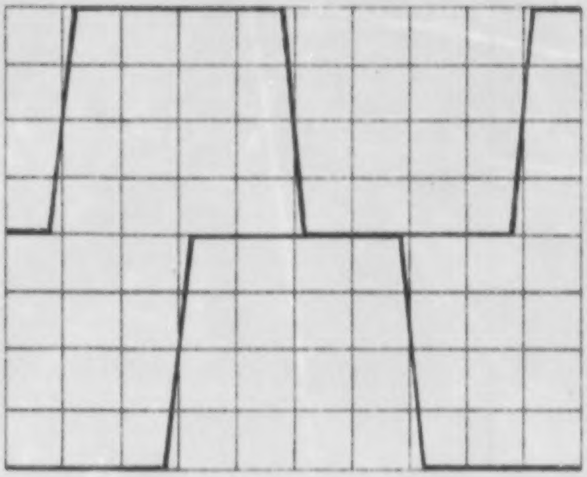
FIGURE 31



2. ______________________________ degrees out of phase

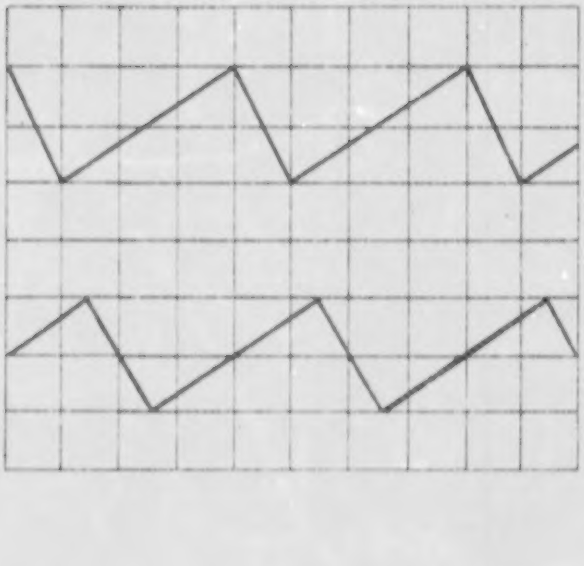
ASSIGNMENT SHEET #6

FIGURE 32



3. ______________________ degrees out of phase

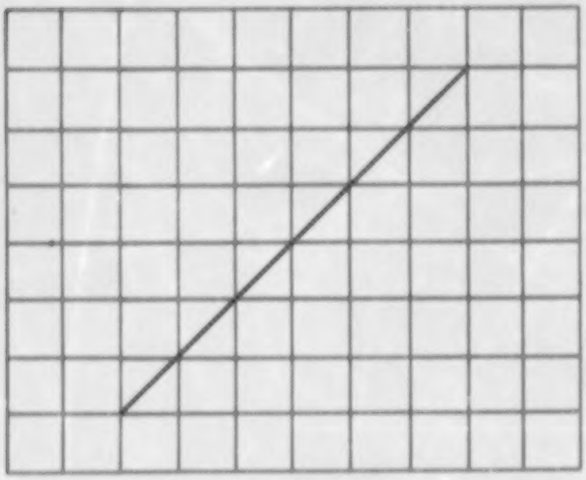
FIGURE 33



4. ______________________ degrees out of phase

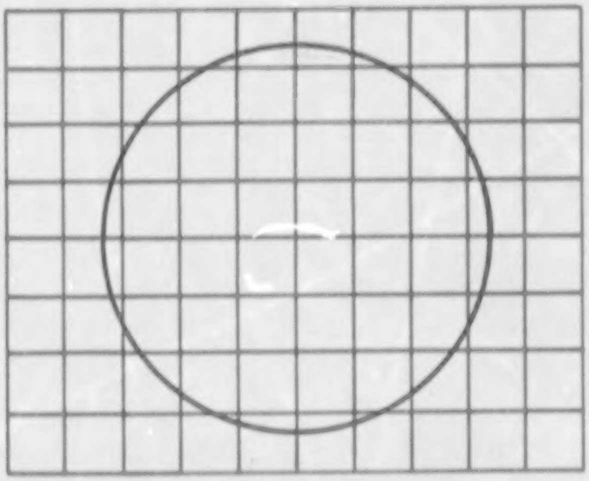
ASSIGNMENT SHEET #6

FIGURE 34



5. ______________________________ degrees out of phase

FIGURE 35



6. ______________________________ degrees out of phase

OSCILLOSCOPE
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. .052 s
2. .428 s
3. 528.7 ms
4. 75,000 ms
5. 6,000 μs
6. .000283 s
7. .0872 s
8. .276 ms
9. 1,370 ms
10. 4,150 μs

Assignment Sheet #2

1. .5 V
2. 100 mV
3. 1,287 mV
4. 1.687 V
5. 2 mV
6. 2.879 V
7. 73,510 mV
8. 167 V
9. 2,000 mV
10. 1 V

Assignment Sheet #3

1. 40 Hz
2. 675 cps
3. .675 kHz
4. 794 cps
5. 1,500,000 Hz
6. 1.5 MHz
7. .987 MHz
8. 3.79 kHz
9. 20 kHz
10. 7 Hz

Assignment Sheet #4

1. 56.56 volts, rms
2. .0707 volts, rms
3. 10.605 volts, rms
4. 28.28 volts, rms

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #5

1. 8 μs; .125 MHz
2. 8 ms; .125 kHz
3. 3 s; .33 Hz
4. .8 ms; 1.25 kHz

Assignment Sheet #6

1. 90°
2. 135°
3. 90°
4. 135°
5. 180°
6. 90°

OSCILLOSCOPE
UNIT II

JOB SHEET #1--SET UP AN OSCILLOSCOPE FOR OPERATION

I. Equipment--Oscilloscope

II. Procedure

A. Connect power cable to oscilloscope

B. Set the following controls to the middle of their range

1. Focus
2. Vertical position
3. Horizontal position
4. Sweep time/cm
5. Volts/cm

C. Set the following controls fully counterclockwise or "OFF"

1. Scale illumination
2. Intensity

D. Set trigger source to "LINE"

E. Turn on power; wait a few seconds for oscilloscope to warm up

F. Turn intensity control clockwise until trace appears across screen

G. If no trace appears, move vertical position control

H. If trace fails to show, repeat steps A through G

(NOTE: Consult the instructor if the trace still fails to appear.)

I. Once trace is visible, adjust the following controls to obtain a clear trace centered on the screen

1. Focus
2. Intensity
3. Vertical position
4. Horizontal position

(NOTE: Ask the instructor to check your resulting trace.)

J. Turn oscilloscope off

K. Put equipment away

OSCILLOSCOPE
UNIT II

JOB SHEET #2--ADJUST OSCILLOSCOPE CONTROLS FOR A STABLE WAVEFORM DISPLAY

I. Equipment and materials

A. Oscilloscope

B. Signal generator

C. Test leads

II. Procedure

A. Set up oscilloscope for operation

B. Turn on signal generator

C. Connect signal generator to oscilloscope

D. Adjust the volts/cm so that the peak-to-peak amplitude is visible on screen

E. Set trigger control to internal position; select channel that has the signal generator as an input

F. Adjust trigger level and slope controls until waveform is stable

G. Set sweep time/cm so that waveform is only a few cycles in length

H. Readjust all controls to obtain the clearest and most stable trace possible

(NOTE: Ask instructor to check your resulting waveform.)

I. Turn off oscilloscope and signal generator

J. Put equipment and materials away

OSCILLOSCOPE
UNIT II

JOB SHEET #3--MEASURE FREQUENCY USING THE OSCILLOSCOPE

I. Equipment and materials

   A. Oscilloscope

   B. Signal generator

   C. Test leads

II. Procedure

   A. Set up the oscilloscope and signal generator for operation

   B. Connect signal generator to oscilloscope

   C. Adjust oscilloscope for a stable waveform

   D. Determine the time of the sine wave

   E. Record your reading

   Sine wave time = ______________________________

   F. Calculate frequency of sine wave

   G. Record the frequency

   Frequency = ______________________________

   (NOTE: Check your answer with the instructor.)

   H. Turn off oscilloscope and signal generator

   I. Put equipment and materials away

OSCILLOSCOPE
UNIT II

JOB SHEET #4--MEASURE AC VOLTAGE USING THE OSCILLOSCOPE

I. Equipment and materials

  A. Oscilloscope

  B. Signal generator

  C. Test leads

II. Procedure

  A. Set up oscilloscope and signal generator for operation

  B. Connect signal generator to oscilloscope

  C. Adjust oscilloscope for a stable waveform

  D. Measure voltages

  E. Record the voltages

  Voltage = ________________________________ Pk-Pk

  Voltage = ________________________________ rms

  (NOTE: Check your answers with the instructor.)

  F. Turn off oscilloscope and signal generator

  G. Put equipment and materials away

OSCILLOSCOPE
UNIT II

JOB SHEET #5--MEASURE DC VOLTAGE USING THE OSCILLOSCOPE

I. Equipment and materials

   A. Dual-trace oscilloscope

   B. DC power supply

   C. Test leads

II. Procedure

   A. Set up oscilloscope and power supply for operation

   B. Connect power supply to oscilloscope

   C. Adjust oscilloscope to measure DC voltage

   D. Measure voltage

   E. Record your results

   Voltage = ______________________________

   (NOTE: Check your answer with the instructor.)

   F. Turn off oscilloscope and power supply

   G. Put equipment and materials away

OSCILLOSCOPE
UNIT II

JOB SHEET #6–DETERMINE PHASE RELATIONSHIPS OF AC SIGNALS USING THE OSCILLOSCOPE

I. Equipment and materials

- A. Dual-trace oscilloscope
- B. Oscilloscope probes–2 each, 10X
- C. Three-phase power source

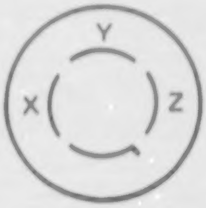
  EXAMPLES: Three-phase AC motor, three-phase circuit breaker, three-phase wall outlet

II. Procedure

- A. Set up oscilloscope near power source
- B. Connect oscilloscope between two points of power source

  EXAMPLE: Points X and Y in Figure 36

FIGURE 36



3-ϕ Plug

- C. Adjust oscilloscope for specified voltage and frequency
- D. Measure phase difference and record below

  ______________________ degrees out of phase

- E. Disconnect one lead and reconnect to power source

  EXAMPLE: Points X and Z in Figure 36

- F. Measure phase difference and record below

  ______________________ degrees out of phase

- G. Disconnect other lead and reconnect to power source

  EXAMPLE: Points Y and Z in Figure 36

JOB SHEET #6

H. Measure phase difference and record below

______________________________ degrees out of phase

(NOTE: Discuss your results with the instructor.)

I. Turn off oscilloscope and disconnect equipment

J. Put equipment and materials away

OSCILLOSCOPE
UNIT II

JOB SHEET #7--CALIBRATE AN OSCILLOSCOPE PROBE

I. Equipment and materials

   A. Oscilloscope

   B. Oscilloscope probe

II. Procedure

   A. Set up oscilloscope for operation

   B. Connect oscilloscope probe to oscilloscope input

   C. Connect probe to calibration jack on oscilloscope

   D. Adjust oscilloscope for stable square wave display on cathode-ray tube

   E. Check square wave signal for distortion in signal

   F. Adjust oscilloscope probe for no distortion in displayed signal

   (NOTE: If the square wave signal has no distortion, vary adjustment watching for distortion. If distortion cannot be eliminated, notify instructor. Have instructor check your work.)

   G. Put equipment and materials away

OSCILLOSCOPE
UNIT II

TEST

NAME ______________________________________ SCORE ________________

1. Match terms associated with using the oscilloscope to their correct definitions. Write the correct numbers in the blanks.

______a. Device used to initiate the sweep or trace, usually at rate of thousands of times each second or more

______b. Variable control for fine adjustment

______c. Device connecting oscilloscope to circuits to be analyzed

______d. Instrument that produces an image of voltage on a cathode-ray tube screen

______e. Height of a waveform

______f. Grid lines on face of oscilloscope screen

______g. Waveform having smooth and rounded peaks, uniformly spaced and proportioned

______h. Measurement of effectiveness of waveform in supplying power

______i. Action of the image-producing beam as it flashes across oscilloscope screen

______j. Visual representation of voltage showing changes to within fractions of a second

______k. Waveform section that is continuously repeated

1. Oscilloscope
2. Voltage waveform
3. Sine wave
4. Amplitude
5. Cycle length
6. Vernier
7. Sweep
8. Probe
9. Effective voltage
10. Graticule
11. Trigger

2. List main uses of an oscilloscope.

a. ____

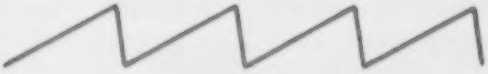
b. ____

c. ____

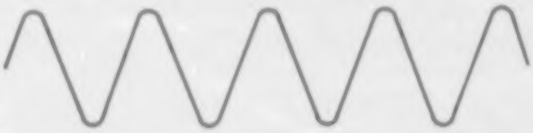
d. ____

TEST

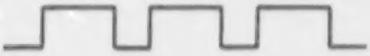
3. Label the main voltage waveforms. Write the correct answers in the blanks beneath each waveform.



a. ____________________



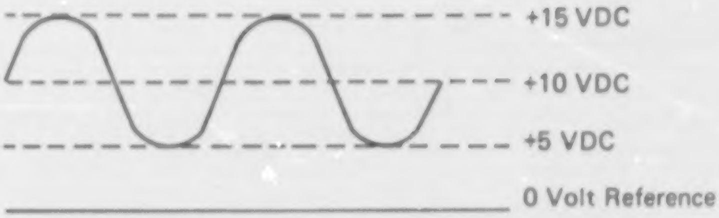
b. ____________________



c. ____________________

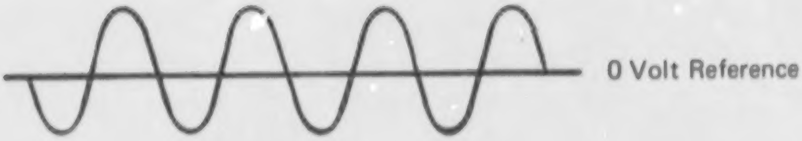
4. Identify AC and DC voltage waveforms. Write the correct answers in the blanks.

Sine wave
Rectangular wave
Positive DC
Negative DC
AC sine wave riding a positive 10 VDC level
AC sine wave riding a negative 10 VDC level

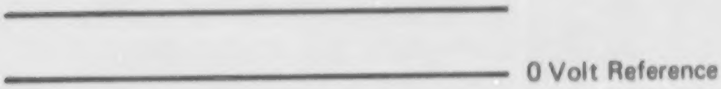


a. ____________________

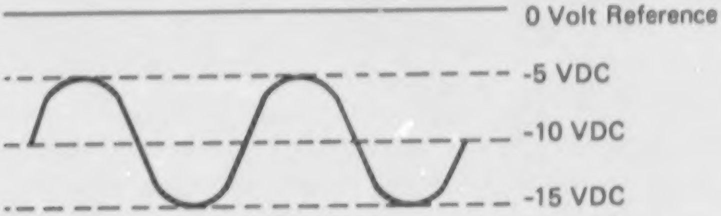
TEST


0 Volt Reference

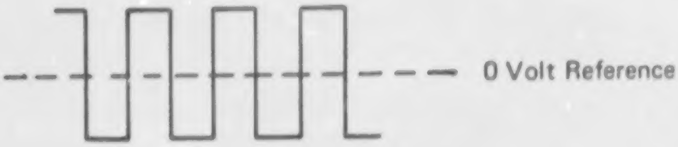
b. ______________________________


0 Volt Reference

c. ______________________________

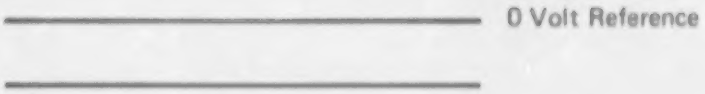

0 Volt Reference
-5 VDC
-10 VDC
-15 VDC

d. ______________________________


0 Volt Reference

e. ______________________________

TEST



f. ____

5. Match basic controls of a dual-trace oscilloscope to their correct functions. Write the correct numbers in the blanks.

_____ a. Selects which channel's voltage waveform will initiate sweep if trigger source is selected for "INT" or internal

_____ b. Selects signal that must initiate or trigger sweep

_____ c. Lights the screen and graticule

_____ d. Provides connection of cable and probe through which voltage waveforms will be monitored

_____ e. Selects which channel will be displayed on screen

_____ f. Turns oscilloscope on and off

_____ g. Positions image up and down on screen by changing the polarity of voltage applied to the vertical deflection plates

_____ h. Provides a rectangular calibration signal to check accuracy of the oscilloscope

_____ i. Selects voltage level of triggering waveform that initiates sweep

_____ j. Adjusts image clarity of electrons being pulled forward by accelerating anode by concentrating into a fine beam both the focusing and the accelerated anode

1. Power switch
2. Scale illumination
3. Focus
4. Cal
5. CH A Input and CH B Input
6. Sweep mode
7. Trigger level
8. VERT POS
9. Trigger channel
10. Trigger source

TEST

_____k. Selects vertical display amplitude

_____l. Adjusts image brightness by limiting the number of electrons allowed to reach the face of the cathode-ray tube

_____m. Moves image to right or left across screen by changing the polarity of the voltage to the horizontal deflection plates

_____n. Provides connection of external voltage waveform to trigger sweep

_____o. Selects part of triggering waveform, positive or negative, that initiates sweep

_____p. Provides control of sweep by external voltage waveform

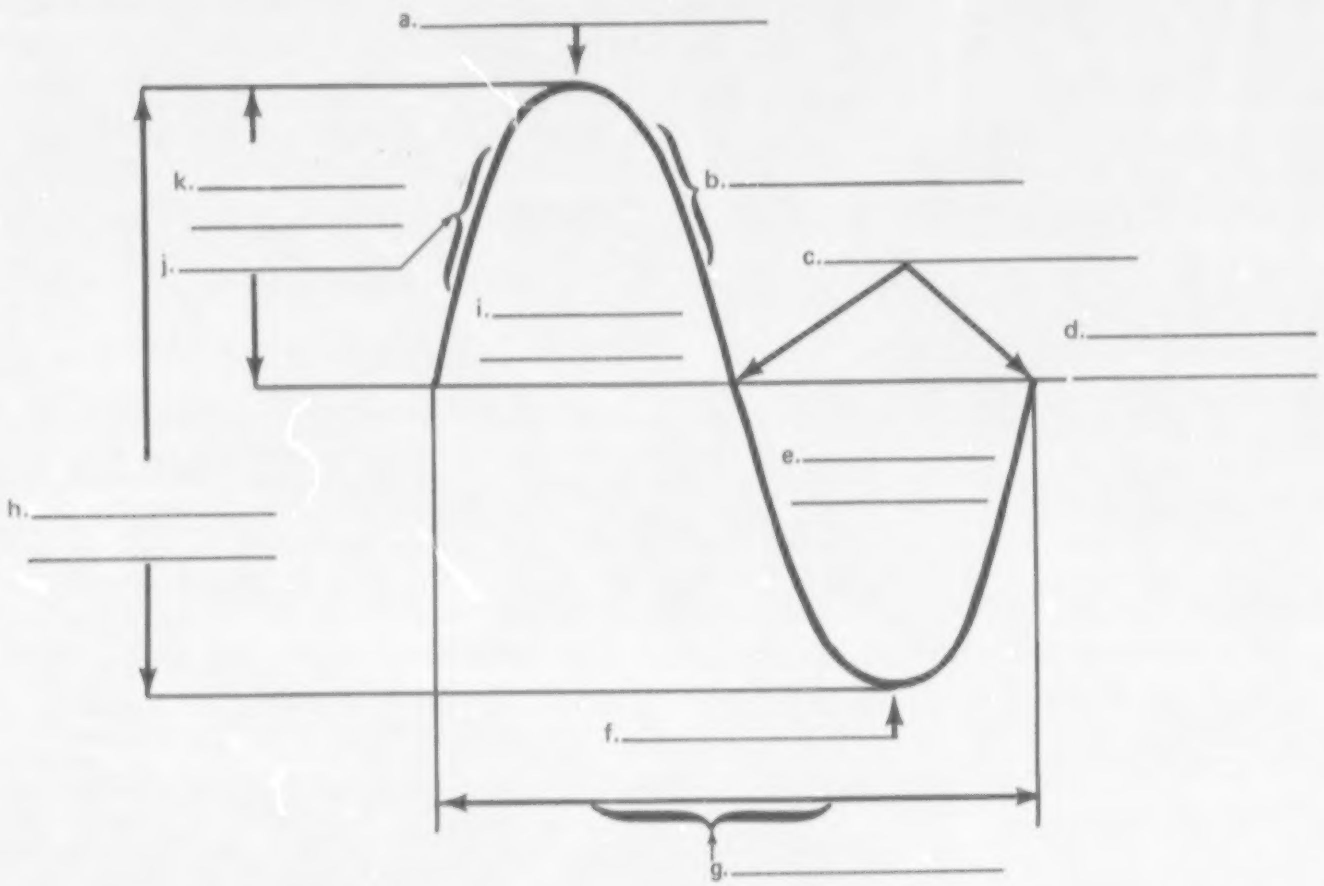
_____q. Selects horizontal sweep rate by expanding and compressing the sine wave in the horizontal direction

_____r. Selects between DC or AC connections

11. Volts/cm
12. EXT TRIG
13. EXT HORIZ INPUT
14. Sweep time/cm
15. Intensity
16. Coupling
17. Trigger slope
18. Horizontal position

TEST

6. Label AC sine wave components shown in the diagram below. Write the correct answers in the blanks provided.

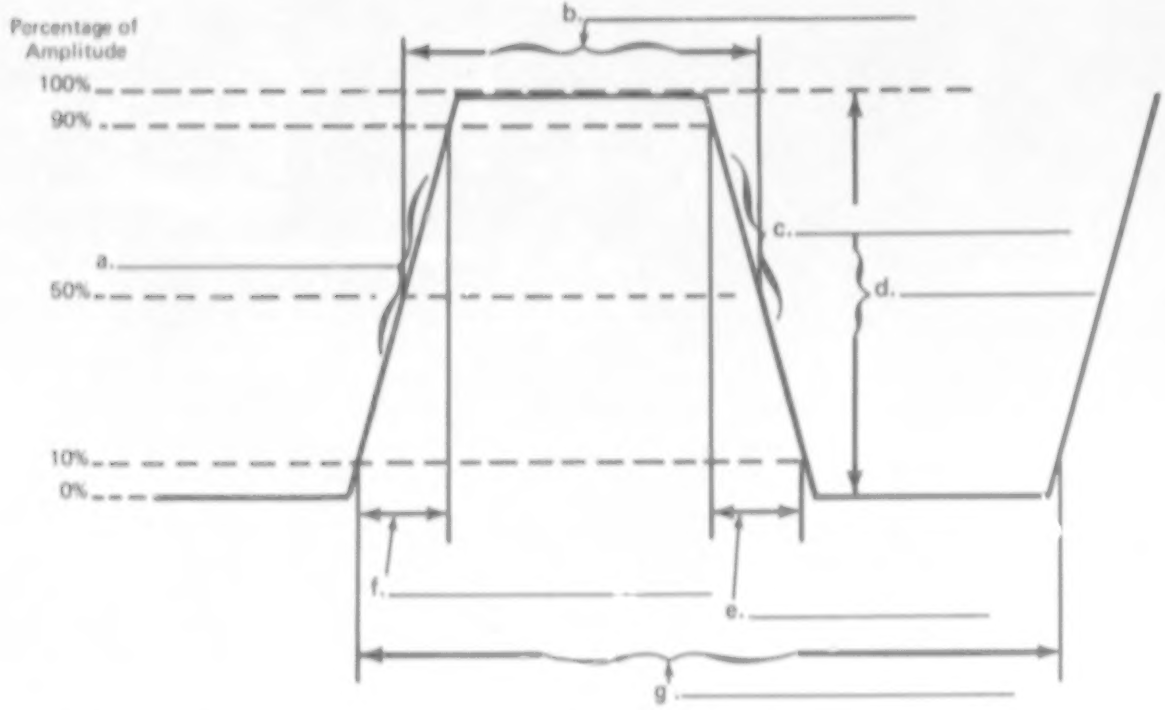


TEST

7. Identify rectangular wave components shown in the diagram below. Write the correct names in the blanks provided.

Pulse width
Fall time
Rise time
One complete cycle

Trailing edge
Leading edge
Amplitude



Percentage of Amplitude
100%
90%
50%
10%
0%
a. ____
b. ____
c. ____
d. ____
e. ____
f. ____
g. ____

TEST

8. Convert units of time to their decimal equivalents. Write the correct answers in the blanks.

   a. 30,000 ms = ______________________ s

   b. 450 ms = ______________________ s

   c. 500 ms = ______________________ s

9. Convert units of voltage to their decimal equivalents. Write the correct answers in the blanks.

   a. 235 mV = ______________ V

   b. .006 V = ______________ mV

   c. 4.6 mV = ______________ V

10. Convert units of frequency to their decimal equivalents. Write the correct answers in the blanks.

    a. 3500 kHz = ______________ MHz

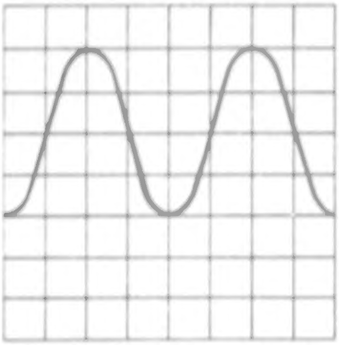
    b. .007 MHz = ______________ kHz

    c. .0042 kHz = ______________ cps

11. Calculate effective or root-mean-square voltage from oscilloscope sine wave dimensions. Write the correct answers in the blanks.

    a. Volts/cm set at 5

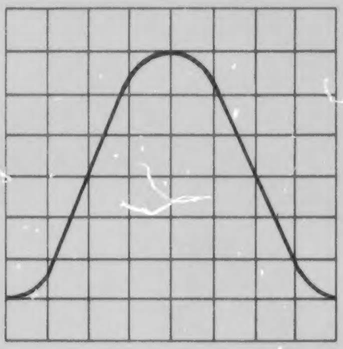
    Probe is 1X ______________________________ volts, rms



TEST

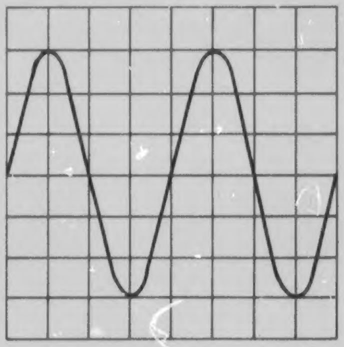
b. Volts/cm set at .2

Probe is 10X ______________________ volts, rms

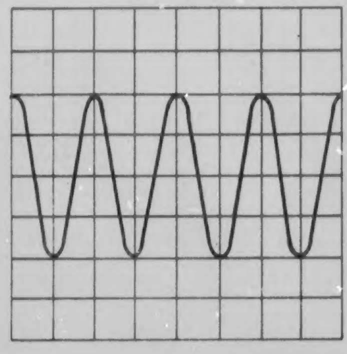


12. Calculate time and frequency from oscilloscope waveform dimensions. Write the correct answers in the blanks.

a. Time per centimeter set at 2 ms/cm = ______________ Hz

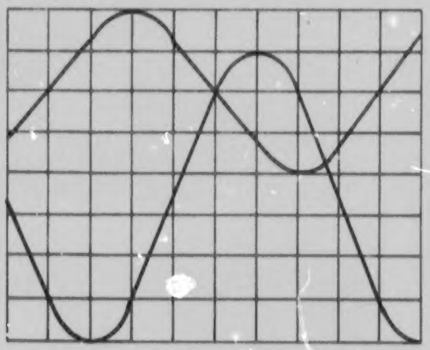


b. Time per centimeter set at 5 μs/cm = ______________ kHz

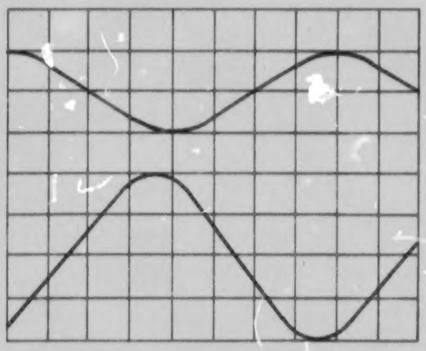


TEST

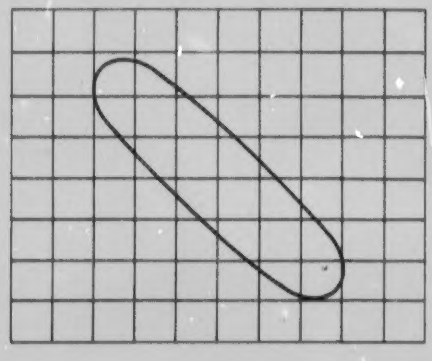
13. Determine phase relationships of AC signals. Write the correct answer in the blanks below each AC signal.



a. ______________________________

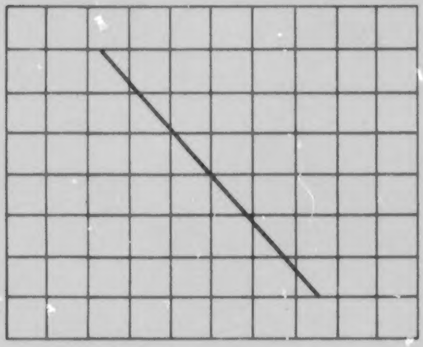


b. ______________________________



c. ______________________________

TEST



d. ____

14. Arrange in order steps for calibrating an oscilloscope probe. Write a "1" before the first step, a "2" before the second step, and so on.

______a. Adjust calibration adjust until square wave has no distortion

______b. Connect oscilloscope probe to Channel A or B vertical input

______c. Check square wave signal for distortion

______d. Locate calibration adjust on oscilloscope probe

______e. Turn on oscilloscope

______f. Adjust oscilloscope for steady trace

______g. Insert test probe into calibration jack on oscilloscope

______h. Adjust the volts/cm control for a setting which will allow one peak-to-peak signal to be visible on the cathode-ray tube

(NOTE: The job sheets are listed in test question 15. They are an important part of this unit. If they have not been completed, check with your instructor.)

15. Demonstrate the ability to

a. Set up an oscilloscope for operation.

b. Adjust oscilloscope controls for a stable waveform display.

c. Measure frequency using the oscilloscope.

d. Measure AC voltage using the oscilloscope.

e. Measure DC voltage using the oscilloscope.

TEST

f. Determine phase relationships of AC signals using the oscilloscope.

g. Calibrate an oscilloscope probe.

OSCILLOSCOPE
UNIT II

ANSWERS TO TEST

1. a. 11
   b. 6
   c. 8
   d. 1
   e. 4
   f. 10
   g. 3
   h. 9
   i. 7
   j. 2
   k. 5

2. a. To view waveform characteristics
   b. To measure frequency
   c. To measure voltage
   d. To compare timing between two different signals

3. a. Triangular or sawtooth waves
   b. Sine waves
   c. Rectangular or square waves

4. a. AC sine wave riding a positive 10 VDC level
   b. AC sine wave
   c. Positive DC
   d. AC sine wave riding a negative 10 VDC level
   e. AC rectangular wave

5. a. 9
   b. 10
   c. 2
   d. 5
   e. 6
   f. 1
   g. 8
   h. 4
   i. 7
   j. 3
   k. 11
   l. 15
   m. 18
   n. 12
   o. 17
   p. 13
   q. 14
   r. 16

ANSWERS TO TEST

6. a. Positive peak
   b. Trailing edge
   c. Zero voltage points
   d. Zero voltage level
   e. Negative half-cycle
   f. Negative peak
   g. One complete cycle
   h. Peak-to-peak amplitude
   i. Positive half-cycle
   j. Leading edge
   k. Zero-to-peak amplitude
7. a. Leading edge
   b. Pulse width
   c. Trailing edge
   d. Amplitude
   e. Fall time
   f. Rise time
   g. One complete cycle
8. a. 30 s
   b. .45 s
   c. .50 s
9. a. .235 V
   b. 6 mV
   c. .0046 V
10. a. 3.5 MHz
   b. 7 kHz
   c. 4.2 cps

ANSWERS TO TEST

11. a. 7.07 volts, rms

    b. 4.24 volts, rms

12. a. 125 Hz

    b. 100 kHz

13. a. 135°

    b. 157.5°

    c. 45°

    d. 0°

14. a. 8

    b. 3

    c. 6

    d. 7

    e. 1

    f. 2

    g. 5

    h. 4

15. Performance skills evaluated to satisfaction of instructor

RESISTORS
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to identify the value of resistors and specify a replacement through resistor indications and through the use of a multimeter. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with resistors to their correct definitions.
2. Label resistor circuit symbols.
3. Match various types of resistor constructions to their correct advantages.
4. Determine resistance values by using the resistor color code.
5. List specifications that describe a replacement resistor.
6. Label letter symbols associated with resistors.
7. Label resistive circuit configurations.
8. Calculate equivalent resistance of series resistors.
9. Calculate equivalent resistance of parallel resistors.
10. Using their color bands, determine the size and tolerance of resistors.
11. Calculate the acceptable tolerance range of resistors.
12. Identify the size and tolerance of resistors by color bands, without referring to a color-code list.
13. Identify watt rating by resistor size.
14. Specify a replacement for resistors.
15. Demonstrate the ability to
    a. Determine resistor size by using a multimeter.
    b. Test a potentiometer by using a multimeter.

RESISTORS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparency.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Prepare an assortment of resistor types for display.

   EXAMPLES: Potentiometers; wire-wound, large tapped resistors; several sizes of fixed resistors; rheostat; thermistors

   H. Construct a large mock-up resistor from a cylindrically shaped can or box by running a heavy wire through the center for leads, painting with color bands, and using for demonstration.

   I. Find a complex circuit schematic, and have students identify resistors on the schematic.

   J. Give test.

II. Instructional materials

   A. Objective sheet

   B. Information sheet

   C. Transparency master--TM #1--Resistors

   D. Assignment sheets

      1. Assignment Sheet #1--Calculate the Equivalent Resistance of Resistors in Series

      2. Assignment Sheet #2--Calculate the Equivalent Resistance of Resistors in Parallel

      3. Assignment Sheet #3--Using Their Color Bands, Determine the Size and Tolerance of Resistors

      4. Assignment Sheet #4--Calculate the Acceptable Tolerance Range of Resistors

SUGGESTED ACTIVITIES

5. Assignment Sheet #5--Identify the Size and Tolerance of Resistors by Color Bands, Without Referring to a Color-Code List

6. Assignment Sheet #6--Identify Watt Rating by Resistor Size

7. Assignment Sheet #7--Specify a Replacement for Resistors

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1--Determine Resistor Size by Using a Multimeter

2. Job Sheet #2--Test a Potentiometer by Using a Multimeter

G. Test

H. Answers to test

III. Unit references

A. Loper, Orla E. *Direct Current Fundamentals.* Albany, New York: Delmar Publishers, 1959.

B. Seippel, Robert G. *Direct Current Circuit Analysis.* Chicago: American Technical Society, 1975.

RESISTORS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Resistor--Device used in electrical and electronic circuits which opposes the flow of electrons

B. Resistance--Amount of opposition to electron flow of a resistor; measured in ohms

C. Fixed resistor--Device designed to create a specific amount of resistance

D. Variable resistor--Device designed to create a varying amount of resistance

E. Potentiometer--Variable resistor using three connecting points in a circuit; used to tap variable amounts of voltage

F. Rheostat--Variable resistor using only two connections in the circuit; used to vary circuit current flow

G. Tapped resistor--Wire-wound resistor having one or more terminals along its length in order to tap various amounts of resistance

H. Wire-wound resistor--Resistor constructed of resistive wire wound around an insulating core material

I. Carbon-composition resistor--Resistor constructed of a fine carbon material divided by a powdered insulating material

J. Carbon-film resistor--Resistor constructed of a fine carbon coating around an insulating material

K. Metal-film resistor--Resistor constructed of a conductive coating over a glass substrate

L. Cermet-film resistor--Resistor constructed of a carbon coating fired onto a solid ceramic subtrate; usually found on printed circuit boards

M. Substrate--Supporting material to which other materials adhere

N. Resistor tolerance--Permissible deviation from the specified resistive value

O. Ohm--Unit of measurement of the resistance to the flow of electrons

P. Watt--Unit of measurement of power

Q. Series circuit--Circuit in which the components are connected end-to-end

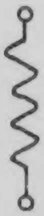
R. Parallel circuit--Circuit in which the components are connected side-by-side

INFORMATION SHEET

II. Resistor circuit symbols (Figures 1-9)

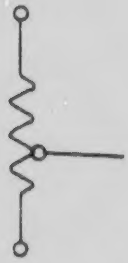
A. Fixed

FIGURE 1



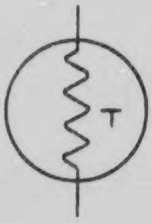
B. Tapped

FIGURE 2



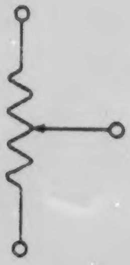
C. Temperature compensated or thermistor

FIGURE 3



D. Potentiometer

FIGURE 4



INFORMATION SHEET

E. Rheostat

FIGURE 5

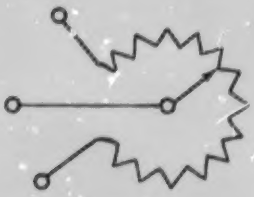


FIGURE 6

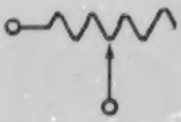
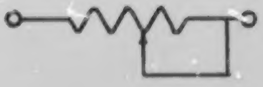
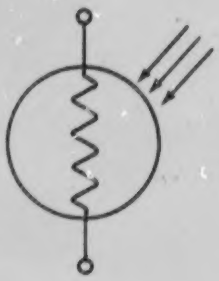


FIGURE 7



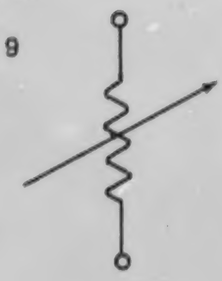
F. Photoconductor

FIGURE 8



G. Variable

FIGURE 9



III. Advantages of various types of resistor constructions

A. Wire-wound--Used where accurate, stable resistance values are required

B. Carbon-composition--Usually enclosed in a plastic case for insulation and mechanical strength

C. Carbon-film--Cost is less than that of carbon-composition resistor

D. Metal-film--Most exact resistance value

E. Cermet-film--Precise resistance values with greater stability in higher temperatures

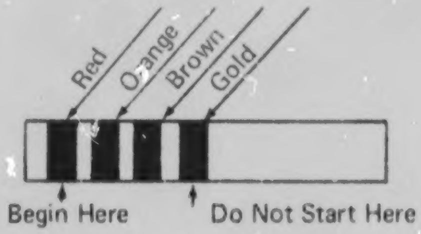
INFORMATION SHEET

IV. Resistance values by use of color code (Transparency #1; Figure 10)

(NOTE: Begin with the color band nearest the end of the resistor.)

EXAMPLE:

FIGURE 10



(NOTE: Colors of the color bands will vary depending on the resistor's resistance value.)

A. The first color band designates the first number of the resistance value

EXAMPLE: Red = 2

B. The second color band designates the second number of the resistance value

EXAMPLE: Orange = 3 or 23

C. The third color band designates the multiplier

EXAMPLE: Brown = 10 or 23 x 10 = 230 ohms

(NOTE: If the third color band is either gold or silver, it is still a multiplier.)

EXAMPLE: Gold third band, 23 x 0.1 = 2.3 ohms

D. The fourth color band designates the tolerance of the resistor

EXAMPLE: Silver = 10%
= 230 ohms x 10%
= 230 x .10
= 23.00

(NOTE: Tolerance is a value above or below the usuable resistance value of the resistor.)

EXAMPLE: 230 ohms + 23 = 253 ohms
230 ohms - 23 = 207 ohms

Therefore, the resistor is good at a value of 207 to 253 ohms

INFORMATION SHEET

V. Specifications that describe a replacement resistor

A. Resistance--Value expressed in ohms

EXAMPLE: 1,200 ohms

B. Tolerance--Value expressed as percentage

EXAMPLE: 5%

C. Power rating--Value expressed in watts

EXAMPLE: 5 watts

D. Type--Description

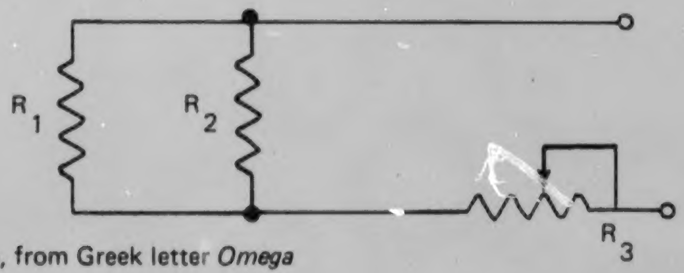
EXAMPLE: Variable

VI. Letter symbols associated with resistors (Figures 11-14)

A. R--Resistor

EXAMPLE:

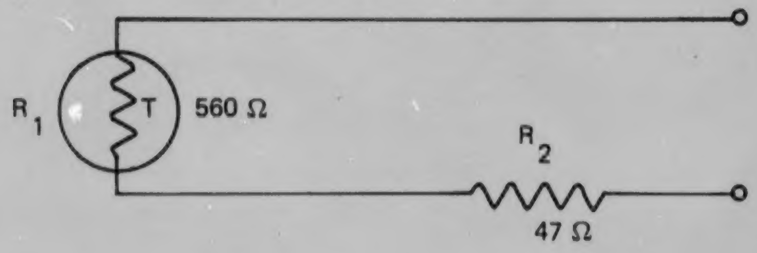
FIGURE 11



B. Ω--Ohm, from Greek letter *Omega*

EXAMPLE:

FIGURE 12

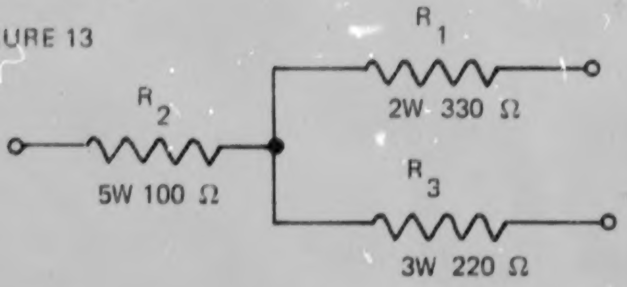


INFORMATION SHEET

C. W--Watt

EXAMPLE:

FIGURE 13

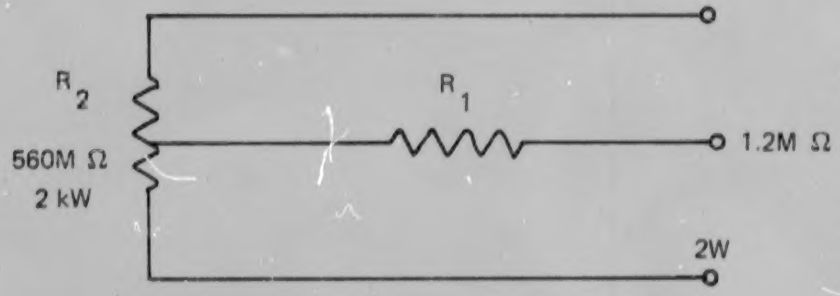

R1
2W 330 Ω
R2
5W 100 Ω
R3
3W 220 Ω

D. Multiplier--Takes place of the zeros in long numbers as follows:

UNIT PREFIX	SYMBOL	MULTIPLIER
1. Giga	G	1,000,000,000 [10^9]
2. Mega	M	1,000,000 [10^6]
3. Kilo	K	1,000 [10^3]
4. Milli	m	.001 [10^{-3}]
5. Micro	μ (Greek, mu)	.000001 [10^{-6}]
6. Nano	n	.000000001 [10^{-9}]
7. Micromicro or pico	$\mu\mu$ or p	.000000000001 [10^{-12}]

EXAMPLES: A 220,000 ohm resistor could be represented as 220K or .22M. A .25 watt resistor could be represented as 250 mW.

FIGURE 14

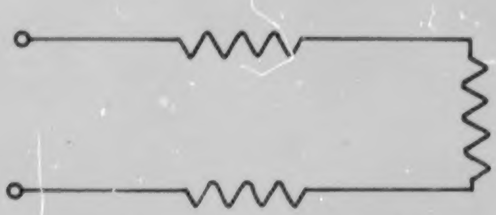

R2
560M Ω
2 kW
R1
1.2M Ω
2W

INFORMATION SHEET

VII. Resistive circuit configurations (Figures 15-17)

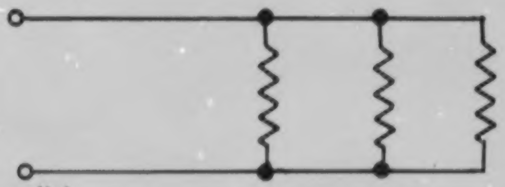
A. Series

FIGURE 15



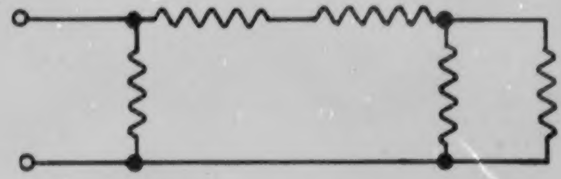
B. Parallel

FIGURE 16



C. Series-parallel

FIGURE 17



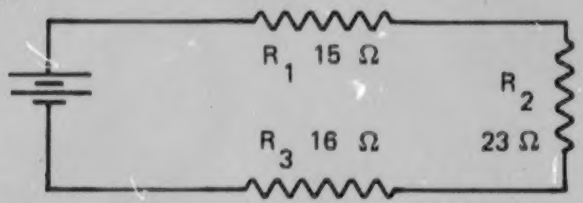
VIII. Calculating equivalent resistance of series resistors (Figure 18)

$$Re = R_1 + R_2 + R_3 \ldots$$

(NOTE: Resistance values are added in order to determine the equivalent or total resistance.)

EXAMPLE:

FIGURE 18



$Re = R_1 + R_2 + R_3$

$= 15\Omega + 23\Omega + 16\Omega$

$= 54\Omega$

INFORMATION SHEET

IX. Calculating equivalent resistance of parallel resistors (Figures 19-21)

(NOTE: Parallel resistance values may be calculated using one of the following three formulas.)

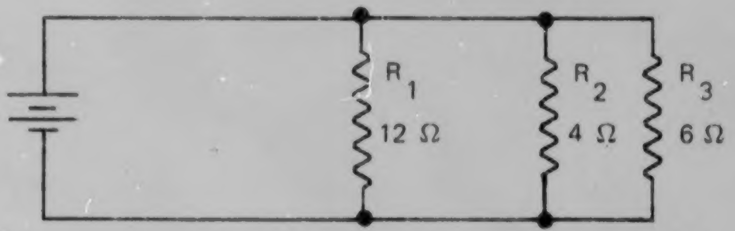
A. Product over the sum method

$$Re = \frac{R_1 \times R_2}{R_1 + R_2}$$

(NOTE: In this method, only two parallel resistors may be calculated at one time.)

EXAMPLE:

FIGURE 19



$$Re = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$= \frac{12\Omega \times 4\Omega}{12\Omega + 4\Omega}$$

$$= \frac{48\Omega}{16\Omega}$$

$$= 3$$

(NOTE: Now that the Re of R_1 and R_2 have been determined, calculate in the same method for total as Re_2.)

$$Re_2 = \frac{Re \times R_3}{Re + R_3}$$

$$= \frac{3\Omega \times 6\Omega}{3\Omega + 6\Omega}$$

$$= \frac{18\Omega}{9\Omega}$$

$$= 2\Omega$$

INFORMATION SHEET

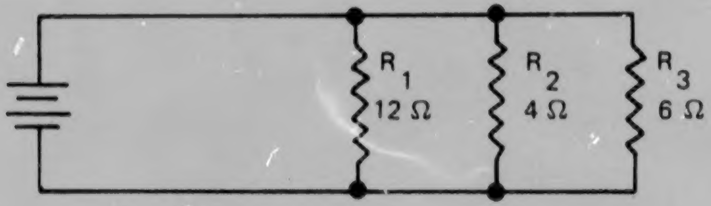
B. Reciprocal method

$$Re = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots}$$

(NOTE: In this method, any number of resistances may be used.)

EXAMPLE:

FIGURE 20



$$Re = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots}$$

$$= \frac{1}{\frac{1}{12\Omega} + \frac{1}{4\Omega} + \frac{1}{6\Omega}}$$

$$= \frac{1}{.083 + .25 + .16}$$

$$= \frac{1}{.493}$$

$$= 2\Omega$$

INFORMATION SHEET

C. Equivalent resistance method

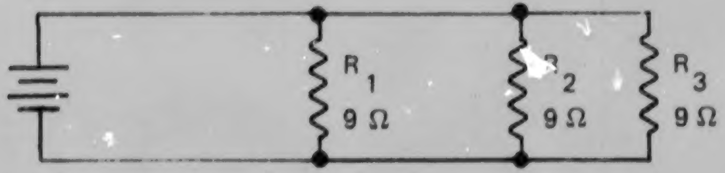
$$Re = \frac{R}{N}$$

R = Resistance
N = Number of resistors

(NOTE: This method will work only when the resistance values are the same.)

EXAMPLE:

FIGURE 21

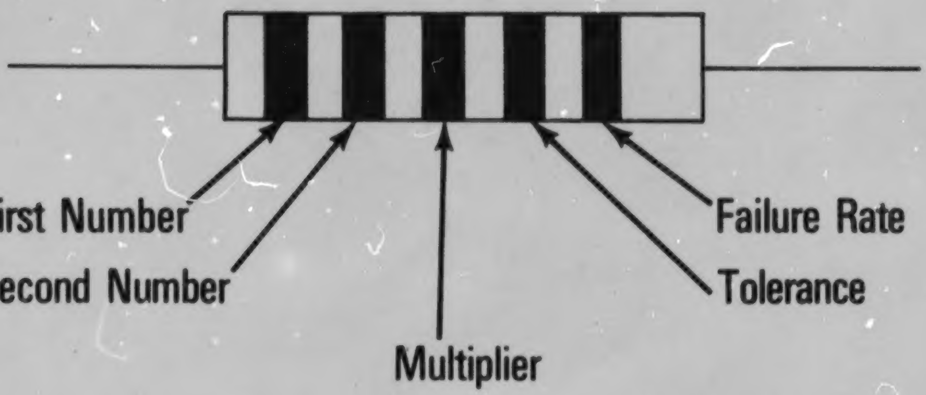


$$Re = \frac{R}{N}$$

$$= \frac{9\Omega}{3\Omega}$$

$$= 3\Omega$$

Resistor Color Chart


First Number
Second Number
Multiplier
Failure Rate
Tolerance

Color	First Number	Second Number	Multiplier	Tolerance	Failure Rate per 1000 hrs.
Black	0	0	1	± 20%	L 5%
Brown	1	1	10	± 1%	M 1%
Red	2	2	100	± 2%	P 0.1 %
Orange	3	3	1000	–	R 0.01 %
Yellow	4	4	10000	–	S 0.001%
Green	5	5	100000	–	T0.0001%
Blue	6	6	1000000	–	
Violet	7	7	10000000	–	
Gray	8	8		–	
White	9	9		–	
Gold	–	–	0.1	± 5%	
Silver	–	–	0.01	± 10%	
No Color	–	–	–	± 20%	

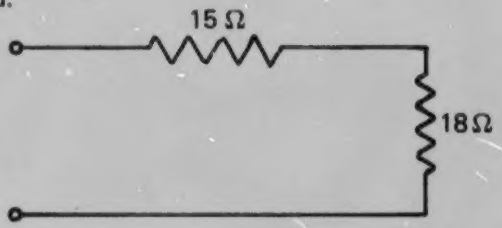
RESISTORS
UNIT I

ASSIGNMENT SHEET #1–CALCULATE EQUIVALENT RESISTANCE OF SERIES RESISTORS

NAME ______________________________ SCORE ______________

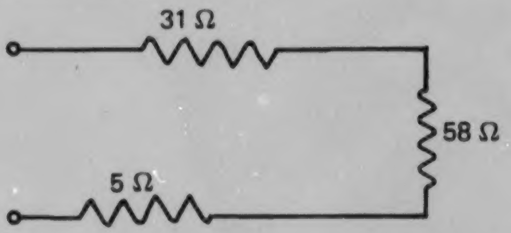
Find the equivalent resistance in each of the following problems (Figures 22-24). Write your answers in the spaces provided.

FIGURE 22



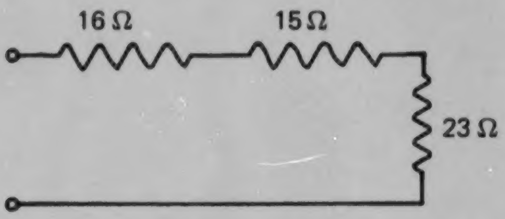
Equivalent resistance = ______________________________

FIGURE 23



Equivalent resistance = ______________________________

FIGURE 24



Equivalent resistance = ______________________________

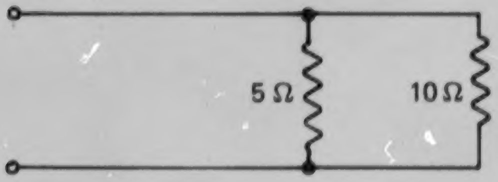
RESISTORS
UNIT I

ASSIGNMENT SHEET #2–CALCULATE EQUIVALENT RESISTANCE OF PARALLEL RESISTORS

NAME ______________________ SCORE ____________

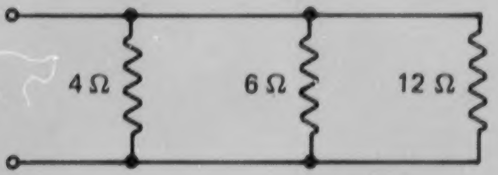
Find the equivalent resistance in each of the following problems (Figures 25-27). Write your answers in the spaces provided.

FIGURE 25



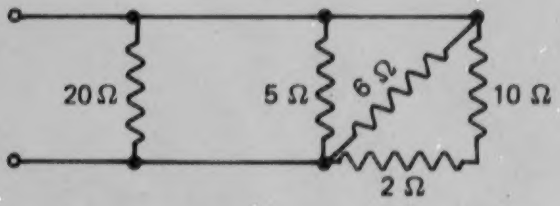
Equivalent resistance = ______________________

FIGURE 26



Equivalent resistance = ______________________

FIGURE 27



Equivalent resistance = ______________________

RESISTORS
UNIT I

ASSIGNMENT SHEET #3--USING THEIR COLOR BANDS, DETERMINE THE SIZE AND TOLERANCE OF RESISTORS

NAME ______________________ SCORE ____________

For each of the color code combinations listed below, write the correct resistor size and tolerance in the space provided

1. Black, brown, brown, silver = ______________________
2. Grey, yellow, blue, none = ______________________
3. Red, white, gold, silver = ______________________
4. Blue, black, black, gold = ______________________
5. Brown, black, brown, gold = ______________________
6. Red, black, green, gold = ______________________
7. Orange, orange, blue, silver = ______________________
8. Orange, white, black, none = ______________________
9. Green, blue, brown, silver = ______________________
10. Yellow, violet, violet, none = ______________________

RESISTORS
UNIT I

ASSIGNMENT SHEET #4–CALCULATE THE ACCEPTABLE TOLERANCE RANGE OF RESISTORS

NAME ______________________________ SCORE ______________

For each resistor listed in Assignment Sheet #3, calculate the acceptable resistor range.

	Resistance	Minimum	Maximum
1.	______	______	______
2.	______	______	______
3.	______	______	______
4.	______	______	______
5.	______	______	______
6.	______	______	______
7.	______	______	______
8.	______	______	______
9.	______	______	______
10.	______	______	______

RESISTORS
UNIT I

ASSIGNMENT SHEET #5--IDENTIFY THE SIZE AND TOLERANCE OF RESISTORS BY COLOR BANDS, WITHOUT REFERRING TO A COLOR-CODE LIST

NAME ______________________________ SCORE ______________

For each resistor given by your instructor, record the color bands in the order they appear and write the resistance and tolerance in the spaces provided below. Do not refer to a list of color codes.

COLOR BANDS

RESISTOR NUMBER	1st color	2nd color	3rd color	4th color	Ohms	Tolerance
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

RESISTORS
UNIT I

ASSIGNMENT SHEET #6–IDENTIFY WATT RATING BY RESISTOR SIZE

NAME ______________________________ SCORE ______________

For each resistor given to you by the instructor, identify the watt rating. Record your answers; then check them with the instructor.

APPROXIMATE STANDARD RESISTOR SIZES

LENGTH INCHES	DIAMETER INCHES	WATT RATING
.15	.06	1/8 watt
.25	.09	1/4 watt
.38	.14	1/2 watt
.56	.23	1 watt
.69	.31	2 watts

RESISTOR NUMBER	YOUR ASSUMED WATT RATING
1	
2	
3	
4	
5	
6	
7	
8	

RESISTORS
UNIT I

ASSIGNMENT SHEET #7–SPECIFY A REPLACEMENT FOR RESISTORS

NAME ______________________ SCORE ____________

For each resistor given to you by the instructor, write the required specifications that describe a replacement resistor.

RESISTOR NUMBER	SPECIFICATIONS FOR REPLACEMENT RESISTOR
1	______________________
2	______________________
3	______________________
4	______________________
5	______________________
6	______________________
7	______________________
8	______________________
9	______________________
10	______________________

RESISTORS
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. 33
2. 94
3. 54

Assignment Sheet #2

1. 3.33
2. 2
3. 2

Assignment Sheet #3

1. 10Ω, 10%
2. 84M, 20%
3. 2.9Ω, 10%
4. 60Ω, 5%
5. 100Ω, 5%
6. 2M, 5%
7. 33M, 10%
8. 39Ω, 20%
9. 560Ω, 10%
10. 470M, 20%

Assignment Sheet #4

1.	10Ω	9Ω	11Ω
2.	84M	67.2M	100.8M
3.	2.9Ω	2.61Ω	3.19Ω
4.	60Ω	57Ω	63Ω
5.	100Ω	95Ω	105Ω
6.	2M	1.9M	2.1M
7.	33M	29.7M	36.3M
8.	39Ω	31.2Ω	46.8Ω
9.	560Ω	504Ω	616Ω
10.	470M	376M	564M

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #5--Evaluated to satisfaction of instructor

Assignment Sheet #6--Evaluated to satisfaction of instructor

Assignment Sheet #7--Evaluated to satisfaction of instructor

RESISTORS
UNIT I

JOB SHEET #1--DETERMINE RESISTOR SIZE BY USING A MULTIMETER

I. Equipment and materials

  A. Multimeter

  B. Assortment of resistors provided by the instructor

II. Procedure

  A. Prepare the multimeter to measure resistance

    1. Set the function switch to +DC

    2. Set the range switch to one of the resistance positions

    3. Observing polarity, connect test leads to multimeter

  B. Connect multimeter across resistor to be measured

  C. Adjust multimeter range switch to reading nearest center, or toward the zero scale

  D. Remove leads from resistor

  E. Connect test leads to each other

  F. Adjust ohms for zero indication on meter

  G. Reconnect test leads to resistor

  H. Determine correct value

  (NOTE: Multiply resistance reading by value indicated by switch position.)

  I. Record the reading below

    1. ______________________
    2. ______________________
    3. ______________________
    4. ______________________
    5. ______________________
    6. ______________________
    7. ______________________
    8. ______________________
    9. ______________________
    10. ______________________

  J. Repeat steps B through H for each resistor being measured

  (NOTE: When all resistors specified by the instructor have been measured, check readings with instructor.)

  K. Put all equipment and materials away

RESISTORS
UNIT I

JOB SHEET #2--TEST A POTENTIOMETER BY USING A MULTIMETER

I. Equipment and materials

A. Multimeter

B. Potentiometer--Specified by instructor

II. Procedure

A. Prepare multimeter to measure resistance

B. Connect multimeter across the two outer connections of the potentiometer

C. While observing the multimeter indication, vary potentiometer from one maximum position to opposite maximum position

D. Is there any change in the resistance reading? ____________________

Why or why not? ____________________________________

E. Remove one test lead from potentiometer; connect it to center connection of the potentiometer.

F. While observing the multimeter indication, vary potentiometer from one maximum position to opposite maximum position

G. Is there any change in the resistance reading? ____________________

Why or why not? ____________________________________

H. Remove other test lead from outer end of potentiometer; connect it to opposite end of potentiometer

I. While observing the multimeter indication, vary potentiometer from one maximum position to opposite maximum position

J. Is there any change in the resistance reading? ____________________

Why or why not? ____________________________________

(NOTE: After completing, potentiometer tests, check results with instructor.)

K. Put all equipment and materials away

RESISTORS
UNIT I

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with resistors to their correct definitions. Write the correct numbers in the blanks.

_____a. Resistor constructed of a conductive coating over a glass substrate

_____b. Variable resistor using only two connections in the circuit; used to vary the circuit current flow

_____c. Circuit in which the components are connected end-to-end

_____d. Circuit in which the components are connected side-by-side

_____e. Wire-wound resistor having one or more terminals along its length in order to tap various amounts of resistance

_____f. Device used in electrical and electronic circuits which opposes the flow of electrons

_____g. Permissible deviation from the specified resistive value

_____h. Unit of measurement of power

_____i. Resistor constructed of a fine carbon material divided by a powdered insulating material

_____j. Device designed to create a specific amount of resistance

_____k. Unit of measurement of the resistance to the flow of electrons

_____l. Resistor constructed of resistive wire wound around an insulating core material

_____m. Variable resistor using three connecting points in a circuit; used to tap variable amounts of voltage

_____n. Amount of opposition to electron flow of a resistor; measured in ohms

1. Resistor
2. Resistance
3. Fixed resistor
4. Variable resistor
5. Potentiometer
6. Rheostat
7. Tapped resistor
8. Wire-wound resistor
9. Carbon-composition resistor
10. Carbon-film resistor
11. Metal-film resistor
12. Cermet-film resistor
13. Substrate
14. Resistor tolerance
15. Ohm
16. Watt
17. Series circuit
18. Parallel circuit

TEST

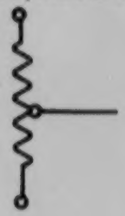
_____o. Supporting material to which other materials adhere

_____p. Resistor constructed of a fine carbon coating around an insulating material

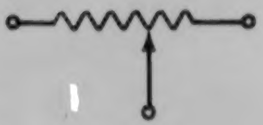
_____q. Resistor constructed of a carbon coating fired onto a solid ceramic substrate; usually found on printed circuit boards

_____r. Device designed to create a varying amount of resistance

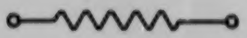
2. Label resistor circuit symbols. Write the correct names in the spaces provided.



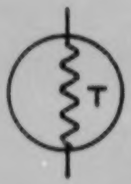
a. ______________________________



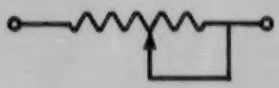
b. ______________________________



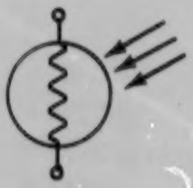
c. ______________________________



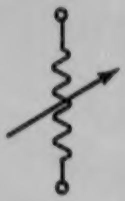
d. ______________________________



e. ______________________________



f. ______________________________



g. ______________________________

TEST

3. Match various types of resistor construction to their correct advantages. Write the correct numbers in the blanks.

_____a. Most exact resistance value

_____b. Used where accurate, stable resistance values are required

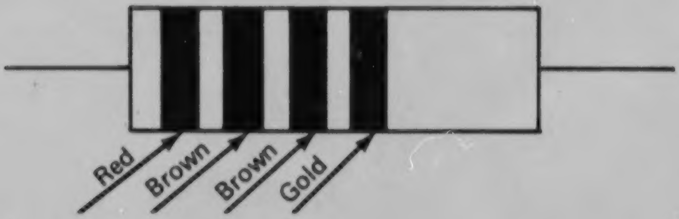
_____c. Usually enclosed in a plastic case for insulation and mechanical strength

_____d. Cost is less than that of carbon-composition resistor

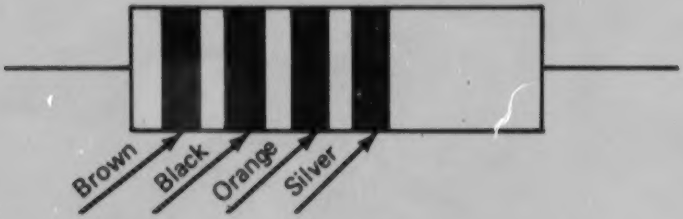
_____e. Precise resistance values with greater stability in higher temperatures

1. Wire-wound
2. Carbon-composition
3. Carbon-film
4. Metal-film
5. Cermet-film

4. Determine resistance values by using the resistor color code. Write the correct answers in the blanks provided.

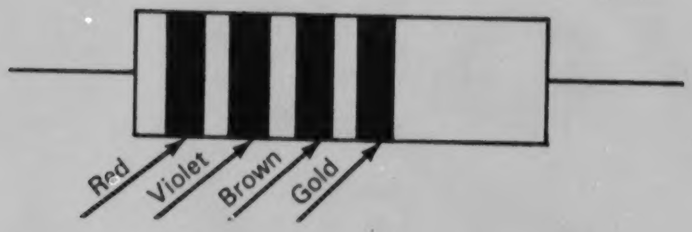


a. ______________________________

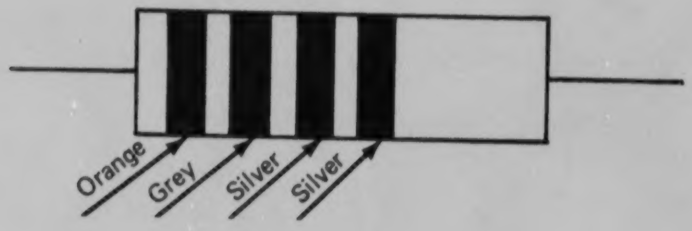


b. ______________________________

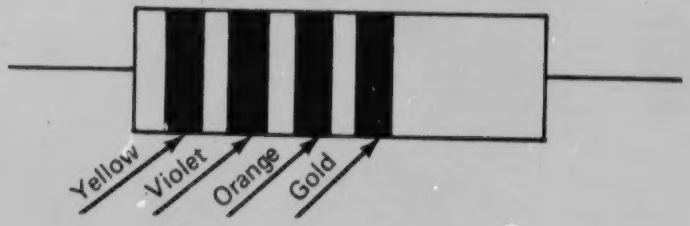
TEST


Red
Violet
Brown
Gold

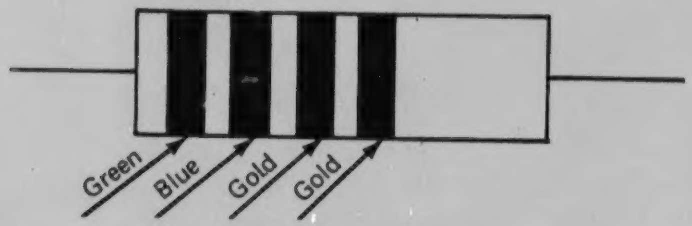
c. ____


Orange
Grey
Silver
Silver

d. ____


Yellow
Violet
Orange
Gold

e. ____


Green
Blue
Gold
Gold

f. ____

TEST

5. List specifications that describe a replacement resistor.

a. ____________________

b. ____________________

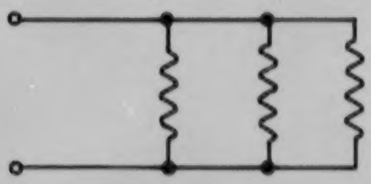
c. ____________________

d. ____________________

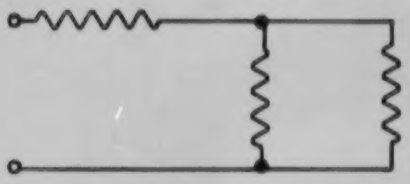
6. Label the letter symbols associated with resistors. Write the correct answers in the blanks.

UNIT PREFIX	MULTIPLIER
a. ____________	W
b. ____________	G = ____________
c. ____________	m = ____________
d. ____________	μ = ____________
e. ____________	Ω
f. ____________	μ μ or p = ____________
g. ____________	M = ____________
h. ____________	k = ____________
i. ____________	R
j. ____________	n = ____________

7. Label the following resistive circuit configurations as series, parallel, or series-parallel circuits. Write the correct names in the spaces provided.

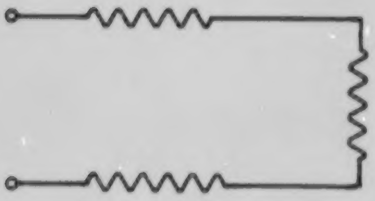


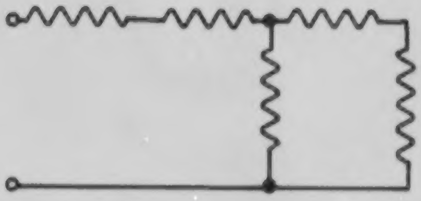
a. ____________________



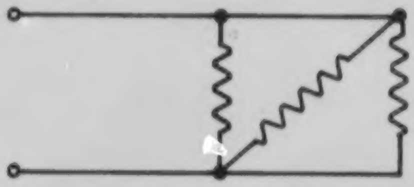
b. ____________________

TEST



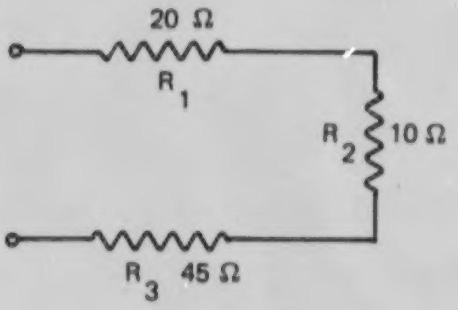


c. ______________________ d. ______________________

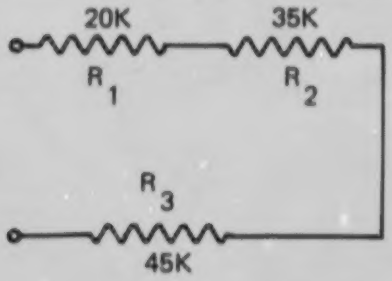


e. ______________________

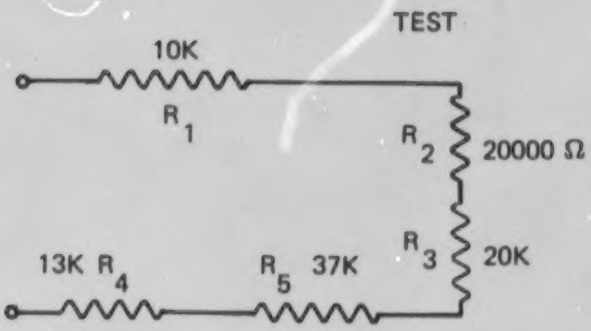
8. Calculate equivalent resistance for each of the following series resistor circuits. Write your answers in the spaces provided.


20 Ω
R1
R2
10 Ω
R3
45 Ω

a. ______________________

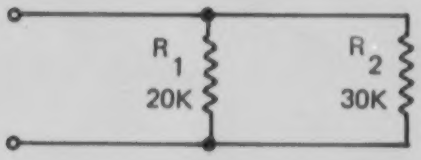

20K
35K
R1
R2
R3
45K

b. ______________________

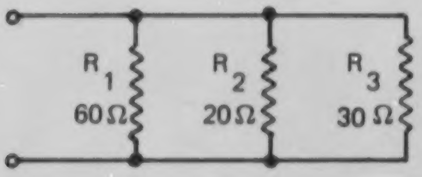

TEST
10K
R1
R2
20000 Ω
R3
20K
13K R4
R5
37K

c. ______________________

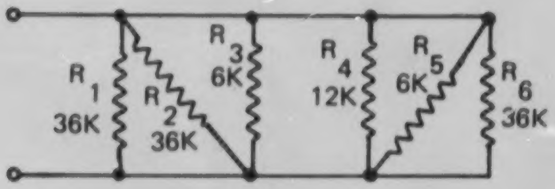
9. Calculate equivalent resistance for each of the following parallel resistor circuits. Write your answers in the spaces provided.


R1
20K
R2
30K

a. ______________________


R1
60 Ω
R2
20 Ω
R3
30 Ω

b. ______________________


R1
36K
R2
36K
R3
6K
R4
12K
R5
6K
R6
36K

c. ______________________

TEST

(NOTE: Test questions 10-15 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

10. Using their color bands, determine the size and tolerance of resistors.

11. Calculate the acceptable tolerance range of resistors.

12. Identify the size and tolerance of resistors by color bands without referring to a color code list.

13. Identify watt rating by resistor size.

14. Specify a replacement for resistors.

15. Demonstrate the ability to

    a. Determine the size of resistors by using a multimeter.

    b. Test a potentiometer by using a multimeter.

RESISTORS
UNIT I

ANSWERS TO TEST

1. a. 11
   b. 6
   c. 17
   d. 18
   e. 7
   f. 1
   g. 14
   h. 16
   i. 9
   j. 3
   k. 15
   l. 8
   m. 5
   n. 2
   o. 13
   p. 10
   q. 12
   r. 4
2. a. Tapped
   b. Pontentiometer
   c. Fixed
   d. Temperature compensated thermistor
   e. Rheostat
   f. Photoconductor cell
   g. Variable
3. a. 4
   b. 1
   c. 2
   d. 3
   e. 5
4. a. 210 ohm, 5% tolerance
   b. 10K ohm, 10% tolerance
   c. 270 ohm, 5% tolerance
   d. .38 ohm, 10% tolerance
   e. 47K ohm, 5% tolerance
   f. 5.6 ohm, 5% tolerance
5. a. Resistance value expressed in ohms
   b. Tolerance value expressed as percentage

ANSWERS TO TEST

c. Power rating expressed in watts

d. Type or description of resistor

6. a. Watt
   - b. Giga 1,000,000,000 [10^9]
   - c. Milli .001 [10^{-3}]
   - d. Micro .000001 [10^{-6}]
   - e. Ohm
   - f. Micromicro or pico .000000000001 [10^{-12}]
   - g. Mega 1,000,000 [10^6]
   - h. Kilo 1,000 [10^3]
   - i. Resistor
   - j. Nano .000000001 [10^{-9}]
7. a. Parallel
   - b. Series-parallel
   - c. Series
   - d. Series-parallel
   - e. Parallel
8. a. 75
   - b. 100K ohms
   - c. 100K ohms
9. a. 12K ohms
   - b. 10 ohms
   - c. 2K ohms
10. Evaluated to satisfaction of instructor
11. Evaluated to satisfaction of instructor
12. Evaluated to satisfaction of instructor
13. Evaluated to satisfaction of instructor
14. Evaluated to satisfaction of instructor
15. Performance skills evaluated to satisfaction of instructor

CAPACITORS
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to determine the effects of AC and DC voltages on capacitors, be able to test capacitors using both the multimeter and the capacitor tester, and describe dangers present while working with capacitors. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with capacitors to their correct definitons.
2. Match abbreviations associated with capacitors to their correct definitions.
3. Label capacitor schematic symbols.
4. Identify common capacitor structures.
5. Label common capacitor markings.
6. Label common capacitor connection arrangements.
7. List capacitor applications in electronics.
8. Distinguish among capacitor parameters.
9. List characteristics of capacitors.
10. Calculate equivalent capacitance in series, parallel, and series-parallel circuits.
11. Describe dangers presented by capacitors.
12. Discuss precautions to take when working with capacitors.
13. Match types of capacitor failures to correct detection techniques.
14. Match capacitor specifications to their correct definitions.
15. List instruments used to test capacitors.
16. Calculate the equivalent capacitance of capacitors in series.
17. Calculate the equivalent capacitance of capacitors in parallel.

SPECIFIC OBJECTIVES

18. Calculate the equivalent capacitance of capacitors in series-parallel.
19. State how capacitor parameters affect capacitance.
20. Write examples of the eight specifications that describe a capacitor.
21. Specify replacements for certain capacitors.
22. Demonstrate the ability to
    a. Observe the effects of a capacitor on both AC and DC voltage.
    b. Use a multimeter to check capacitors.
    c. Operate a capacitor tester.

CAPACITORS
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information and assignment sheets.

   C. Make transparencies

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Find an example of as many types of capacitors discussed in this unit as possible. Show examples to the students.

   H. Give test.

II. Instructional materials

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM #1--Capacitor Construction

      2. TM #2--Plate Area

      3. TM #3--Plate Distance

      4. TM #4--Effect of the Dielectric

      5. TM #5--Electric Field Effect on Capacitors

      6. TM #6--Capacitor Specifications

   D. Assignment sheets

      1. Assignment Sheet #1--Calculate the Equivalent Capacitance of Capacitors in Series

      2. Assignment Sheet #2--Calculate the Equivalent Capacitance of Capacitors in Parallel

      3. Assignment Sheet #3--Calculate the Equivalent Capacitance of Capacitors in Series-Parallel

SUGGESTED ACTIVITIES

4. Assignment Sheet #4--State How Capacitor Parameters Affect Capacitance

5. Assignment Sheet #5--Write Examples of the Eight Specifications that Describe a Capacitor

6. Assignment Sheet #6--Specify Replacements for Certain Capacitors

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1--Observe the Effects of a Capacitor on Both AC and DC Voltage

2. Job Sheet #2--Use a Multimeter to Check Capacitors

3. Job Sheet #3--Operate a Capacitor Tester

G. Test

H. Answers to test

III. Unit reference--Zbar, Paul B. and Joseph G. Sloop. *Electricity-Electronics Fundamentals*. 2nd ed. Englewood Cliffs, New Jersey: McGraw-Hill Book Co., 1977.

CAPACITORS
UNIT II

INFORMATION SHEET

I. Terms and definitions

- A. Noise--Undesirable electronic interference
- B. Waveform--Voltage wave as a representation of voltage changing with time
- C. Oscillator--Circuit or device that produces electronic waves
- D. Function analyzer--Instrument that produces different shapes of electronic waveforms at various frequencies
- E. Series--Circuit of two-lead components connected end-to-end
- F. Parallel--Circuit of two-lead components connected side-by-side
- G. Insulation--Substance that prohibits flow of electricity
- H. Short-circuit--Path for or the action of electricity passing through unintentional conducting materials; usually results in excessive current flow that may cause damage
- I. Dielectric--Insulating substance between plates of capacitor

  EXAMPLES: Paper, oil, ceramic, mica
- J. Power transfer--Movement of electricity from one place to another
- K. Leakage current--Undesirable current flow between capacitor plates due to inability of dielectric material to restrict that flow
- L. Capacitor tester--Instrument that measures capacitance and leakage current
- M. Ohmmeter--Instrument that measures electrical resistance
- N. Open circuit--Disconnection, or broken conductor which restricts electricity from flowing
- O. Electrolytic capacitor--Capacitor that must be connected in only one direction
- P. Farad--Measure of capacitance
- Q. Microfarad--Unit of capacitance equal to one-millionth of a farad; 10^{-6} farad
- R. Micromicrofarad--Unit of capacitance equal to one-trillionth of a farad; 10^{-12} farad

  (NOTE: Micromicrofarad also is known as a *picofarad*.)

INFORMATION SHEET

S. Dual in-line package--Microcircuit package with two rows of seven vertical leads that are easily inserted into an etched circuit board

II. Abbreviations associated with capacitors

A. **C**--Capacitance

B. **DIP**--Dual in-line package

C. **C_e**--Equivalent capacitance

D. **DC**--Direct current

E. **WV**--Working volts

F. **mF, mFd, or µF**--Microfarad

G. **mmF, mmFd, or µµF**--Micromicrofarad

H. **pF, pFd**--Picofarad

I. **V**--Volts

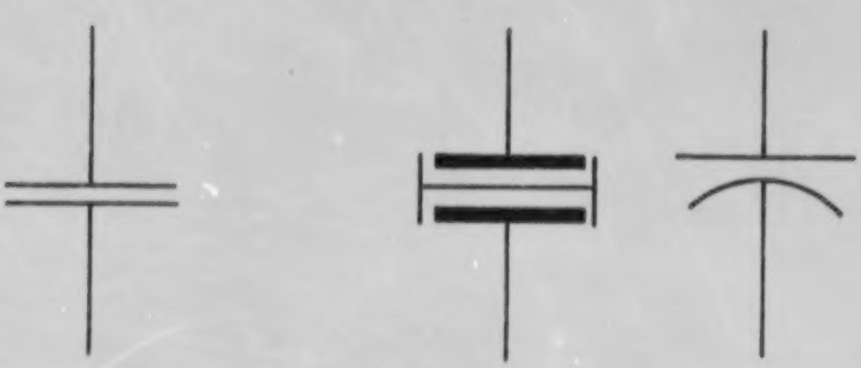
J. **F**--Farad

K. **AC**--Alternating current

III. Capacitor schematic symbols (Figures 1-3)

A. Non-polar capacitor (electrostatic)

FIGURE 1



Old symbol

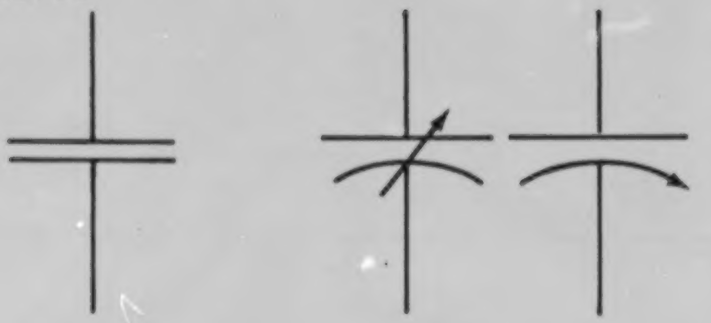
New symbols

(NOTE: The curved side of the schematic diagram usually indicates the side of the capacitor nearest ground.)

INFORMATION SHEET

B. Variable capacitor

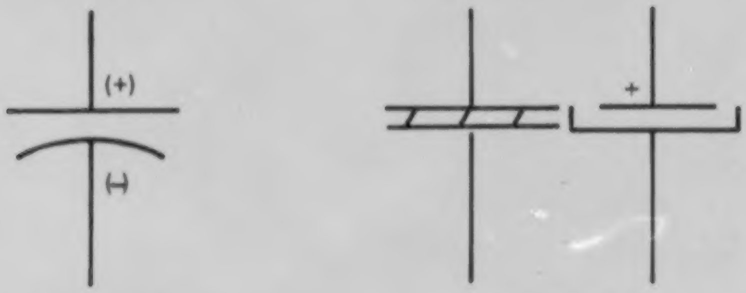
FIGURE 2



Old symbol New symbols

C. Polar capacitor (electrolytic)

FIGURE 3

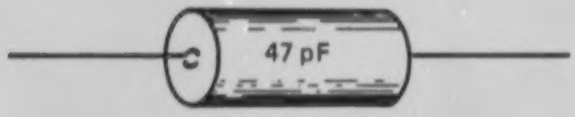


Old symbol New symbols

IV. Common capacitor structures (Figures 4-8)

A. Tubular--Tube or cylinder-shaped

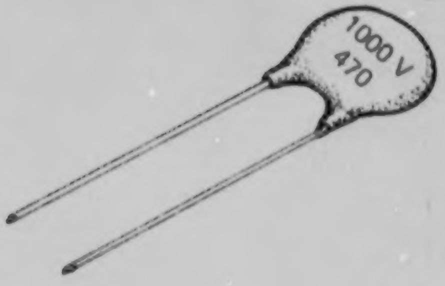
FIGURE 4



INFORMATION SHEET

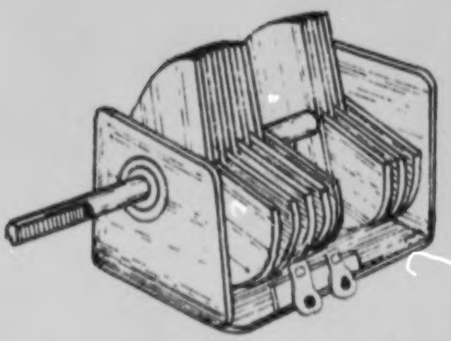
B. Disk or disk-shaped

FIGURE 5



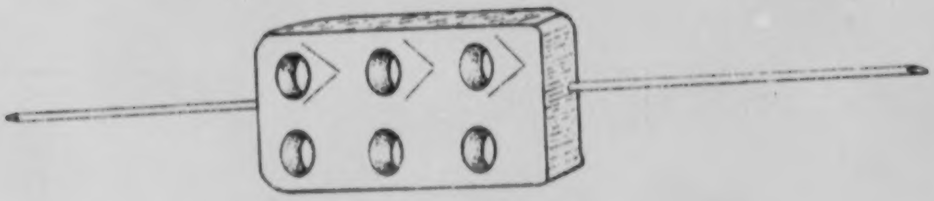
C. Parallel plates

FIGURE 6



D. Rectangular or flat pack

FIGURE 7

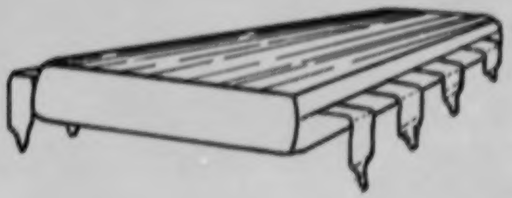


(NOTE: Rectangular, axial-lead, mica capacitors have color dots of one or several color codes.)

INFORMATION SHEET

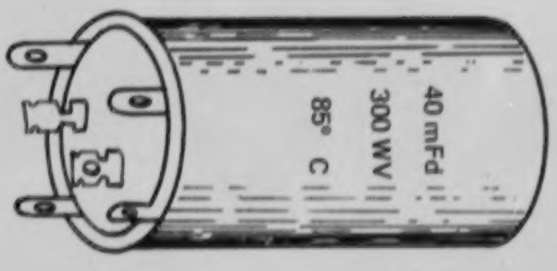
E. Dual in-line package (DIP)

FIGURE 8



F. Aluminum can

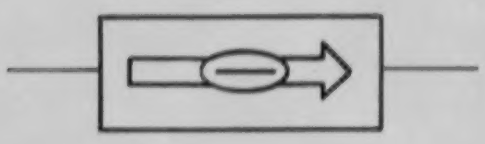
FIGURE 9



V. Common capacitor markings (Figures 10-14)

A. Arrow points toward negative end of a polar capacitor

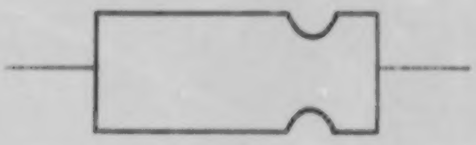
FIGURE 10



INFORMATION SHEET

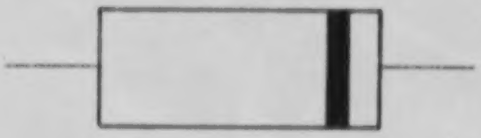
B. Crease in capacitor indicates the positive end of a polar capacitor

FIGURE 11



C. Ring around one end of capacitor indicates the positive end of a polar capacitor

FIGURE 12

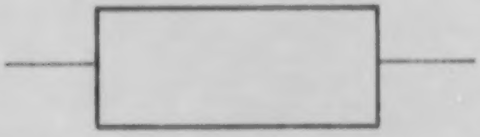


D. Plus sign on one end of capacitor indicates the positive end of a polar capacitor

FIGURE 13

E. No markings indicate that the capacitor is non-polar

FIGURE 14



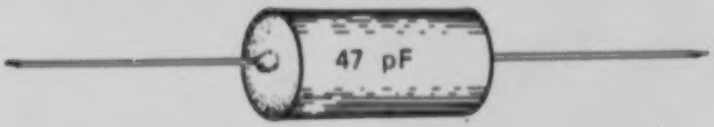
(NOTE: A polar capacitor and an electrolytic capacitor are the same; both must be connected in circuit observing polarity. The non-polar and electrostatic capacitors are also the same; polarity need not be observed.)

INFORMATION SHEET

VI. Common capacitor connection arrangements (Figures 15-17)

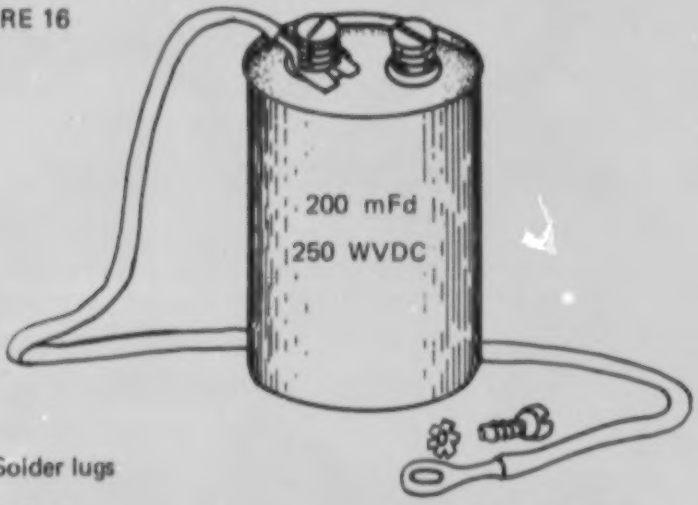
A. Solder leads

FIGURE 15



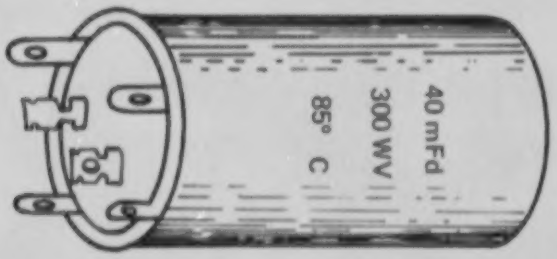
B. Terminal posts

FIGURE 16


200 mFd
250 WVDC

C. Solder lugs

FIGURE 17


40 mFd
300 WV
85° C

INFORMATION SHEET

VII. Capacitor applications in electronics

A. Filters

(NOTE: Capacitors are used to filter noise from circuits and to smooth output voltage of DC power supplies.)

B. Oscillators

(NOTE: Capacitors are used with other components to produce signal outputs of oscillators and function analyzers.)

C. Tuners

(NOTE: Capacitors are used to capture and select specific signal frequencies, as in radio tuners.)

D. Wave shaping

(NOTE: Capacitors can be used to alter the shape of voltage waveforms for particular applications.)

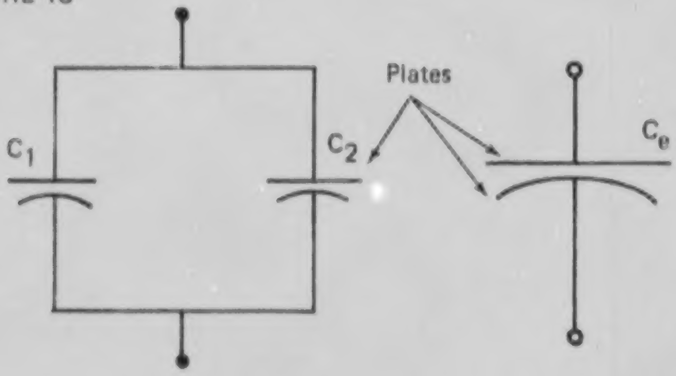
VIII. Ways capacitor parameters affect capacitance (Transparency #1; Assignment Sheet #4)

A. Area of plates (Transparency #2)

1. Capacitance is directly related to plate area
2. Unlike resistors, capacitors of high capacitance are necessarily large
3. If plate area is increased, capacitance is increased

EXAMPLE: Two capacitors in parallel have the same capacitance as one larger capacitor with larger plate areas (Figure 18)

FIGURE 18



628

INFORMATION SHEET

B. Distance between plates (Transparency #3)

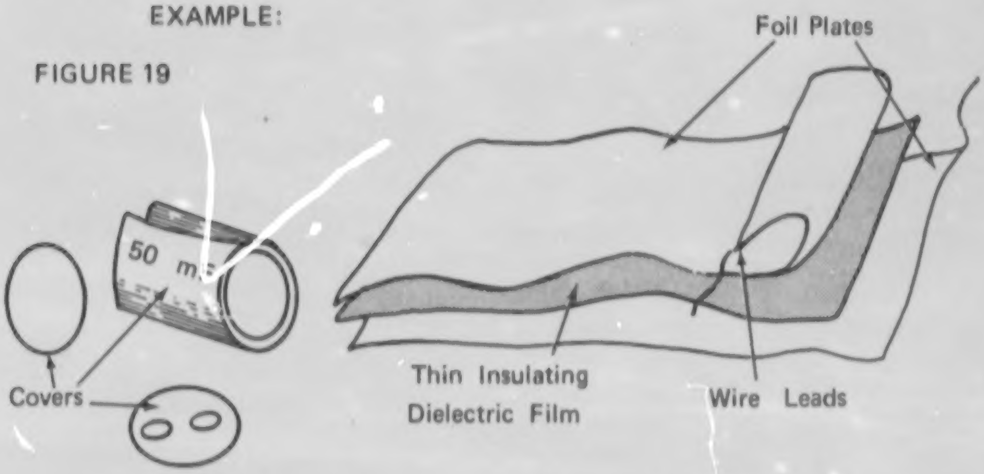
1. Capacitance decreases as plates are spaced apart

2. Plates are assembled very close together to make capacitors as small as possible

3. Close plates require good insulation to keep electricity from short-circuiting across (Figure 19)

EXAMPLE:

FIGURE 19



C. Dielectric constant--Insulating material between capacitor plates can increase capacitance value (Transparency #4)

EXAMPLES: Paper increases capacitance more than air; porcelain increases capacitance more than paper

IX. Characteristics of capacitors

A. Block direct current (DC)

(NOTE: As DC power is applied, maximum current flow exists with minimum voltage until capacitor is completely charged. As additional voltage is applied, nothing else can happen until the capacitor is shorted, thus discharging the capacitor.)

B. Permit flow of alternating current (AC)

(NOTE: Because of the constantly changing direction of AC flow, the capacitor will charge, then discharge, then charge in the opposite direction until power is disconnected.)

INFORMATION SHEET

C. Store electrical energy

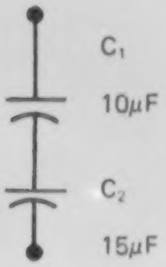
(NOTE: When a voltage is applied, the capacitor will charge. Unless discharged, the capacitor will maintain this charge for a period of time.)

X. Calculating equivalent capacitance in series capacitors, parallel capacitors, and series-parallel capacitors (Assignment Sheets #1, #2, and #3; Figures 20-22)

A. Series capacitors--Equivalent capacitance of two series capacitors is less than the smallest of the two and is equal to the product divided by the sum; use the formula

$$C_e = \frac{C_1 \times C_2}{C_1 + C_2}$$

FIGURE 20



EXAMPLE:

$$\begin{aligned} C_e &= \frac{C_1 \times C_2}{C_1 + C_2} \\ &= \frac{10\ \mu F \times 15\ \mu F}{10\ \mu F + 15\ \mu F} \\ &= \frac{150\ \mu\mu F}{25\ \mu F} \\ &= 6\ \mu F \end{aligned}$$

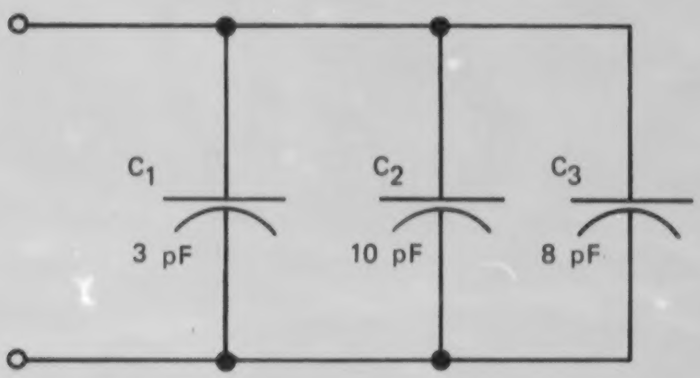
(NOTE: Series capacitance is calculated the same as parallel resistance. Do not confuse the two.)

INFORMATION SHEET

B. Parallel capacitors--Equivalent capacitance of parallel capacitors is equal to the sum of the capacitors; use the formula $C_e = C_1 + C_2 + C_3 \ldots$

EXAMPLE:

FIGURE 21


C_1
3 pF
C_2
10 pF
C_3
8 pF

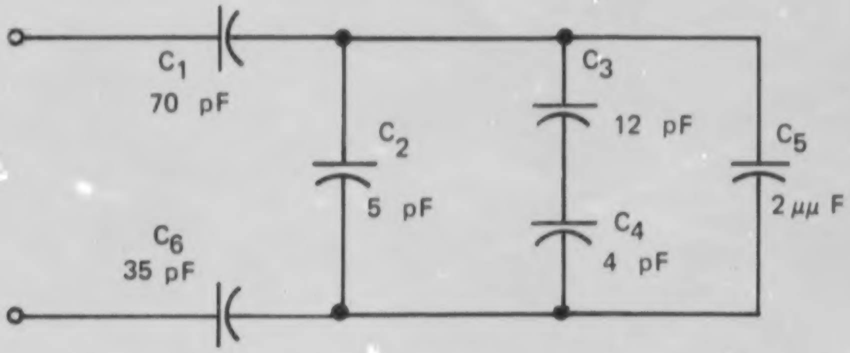
$$C_e = C_1 + C_2 + C_3$$
$$= 3pF + 10pF + 8pF$$
$$= 21pF$$

(NOTE: Capacitance in parallel is calculated the same as resistance in series.)

C. Series parallel capacitors--Calculate series branches, and then parallel branches; finish by calculating any capacitors which are in series with all branches

EXAMPLE:

FIGURE 22


C_1
70 pF
C_2
5 pF
C_3
12 pF
C_4
4 pF
C_5
2 μμ F
C_6
35 pF

INFORMATION SHEET

Calculate C_{e_1} of series branch

$$C_{e_1} = \frac{C_3 \times C_4}{C_3 + C_4}$$

$$= \frac{12\text{ pF} \times 4\text{ pF}}{12\text{ pF} + 4\text{ pF}}$$

$$= \frac{48\text{ ppF}}{16\text{ pF}}$$

$$= 3\text{ pF or } 3\ \mu\mu\text{F}$$

Calculate parallel capacitance of C_2, C_{e_1}, and C_5

EXAMPLE: $C_{e_2} = C_2 + C_{e_1} + C_5$

$$= 5\text{ pF} + 3\text{ pF} + 2\ \mu\mu\text{F}$$

$$= 10\text{ pF or } 10\ \mu\mu\text{F}$$

Calculate C_e of the two series capacitors (C_1 and C_6) and C_{e_2}

EXAMPLE: $C_{e_3} = \dfrac{1}{\dfrac{1}{C_1} + \dfrac{1}{C_6} + \dfrac{1}{C_{e_2}}}$

$$= \frac{1}{\frac{1}{70\text{ pF}} + \frac{1}{35\text{ pF}} + \frac{1}{10\text{ pF}}}$$

$$= 7\text{ pF or } 7\ \mu\mu\text{F}$$

(NOTE: The capacitance equivalence of the above circuit is then 7 pF, or one 7 pF capacitor can replace all six of the above capacitors.)

XI. Capacitor dangers

A. Electrical shock

1. Large capacitors can store enough energy to deliver a fatal electrical shock

2. Small capacitors can cause electrical shocks resulting in serious injury from involuntary muscle reactions

INFORMATION SHEET

B. Explosions

1. Voltage higher than a capacitor's rated working voltage can result in capacitor explosion
2. Rapid charge or discharge of a capacitor involving too sudden a power transfer can result in capacitor explosion
3. An electrolytic capacitor connected in the wrong direction in a circuit is more likely to fail or explode at high voltage

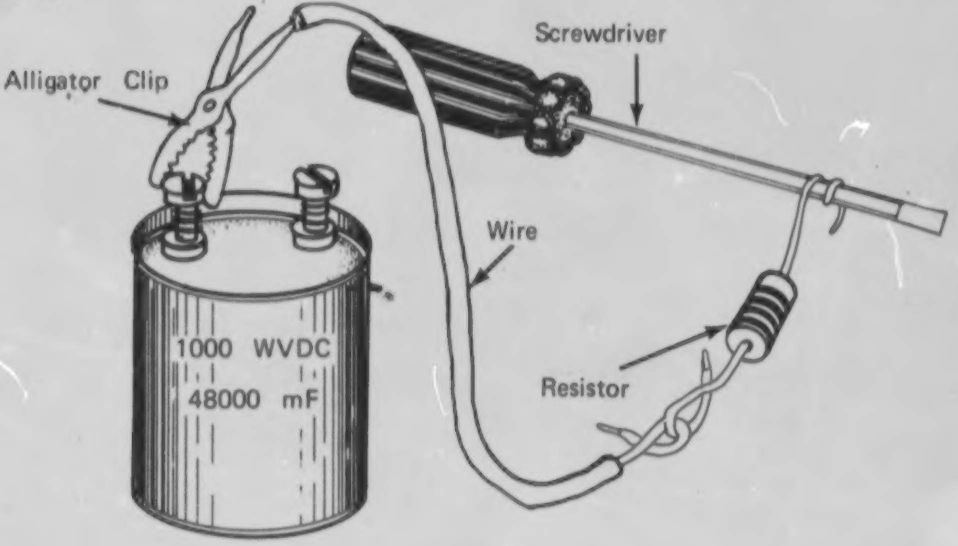
XII. Precautions to take when working with capacitors

A. Discharge capacitors to avoid shock

1. Large capacitors should be discharged through a resistor in order to prevent a large electric arc or sudden power transfer

EXAMPLE: Large capacitor being discharged through a resistor (Figure 23)

FIGURE 23

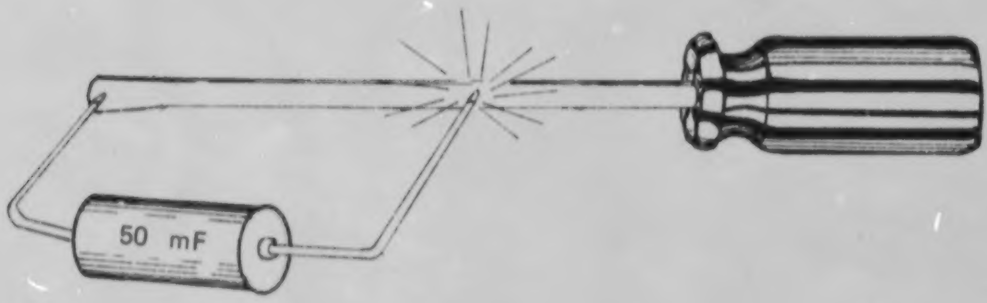


INFORMATION SHEET

2. Small capacitors can be discharged directly

   EXAMPLE: Small capacitor being discharged directly (Figure 24)

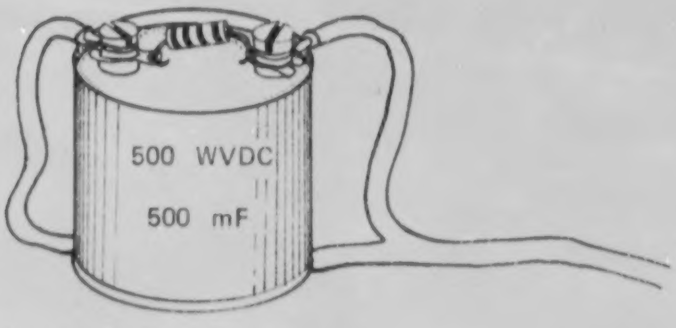
FIGURE 24



3. Bleeder resistors are designed in some circuits to automatically discharge capacitor when power is turned off, but may require a moment to discharge the capacitor completely

   EXAMPLE: Large capacitor with bleeder resistor attached (Figure 25)

FIGURE 25



B. Install capacitors correctly

1. Check capacitors for polarity markings before installing them in circuit

2. Make certain that a capacitor's working voltage is sufficient for application

INFORMATION SHEET

XIII. Capacitor failures and their detection techniques

A. Short circuit--Easily detected with an ohmmeter; meter will indicate a low resistance value

B. Excessive leakage current--Requires capacitor tester to verify; ohmmeter may indicate some resistance between terminals

(NOTE: Capacitor may operate hot and appear to be loading circuit output.)

C. Change in capacitance--Requires a capacitor tester to verify; timing, waveform, or frequency of circuit may be abnormal

D. Open circuit--Requires capacitor tester in most instances to detect; ohmmeter will not deflect and then slowly return to the open or infinite resistance reading as is the usual reaction

XIV. Capacitor specifications (Transparency #6; Assignment Sheets #5 and #6)

A. Capacitance--Ability to store electricity; measured in units called *farads* and *fractions of farads*

EXAMPLE: 47 microfarads

(NOTE: If the capacitor does not indicate μF or pF it is always μF.)

B. Tolerance--Precision with which capacitor is manufactured

EXAMPLE: 10%

(NOTE: If the capacitor does not specify a tolerance, it is 20%.)

C. Polarity--Direction in which certain types of capacitors should be connected in a circuit

(NOTE: An electrolytic or polar capacitor will have its positive lead marked. See Information Sheet V.)

D. Working volts--Maximum DC voltage that may be applied to a capacitor without damaging the capacitor

EXAMPLE: 50 WVDC represents the working volts of DC

E. Structure--Shape of capacitor

EXAMPLES: Tubular, disk, rectangular

F. Function--Application of capacitor

EXAMPLES: Fixed, variable

INFORMATION SHEET

G. Composition--Material of capacitor

EXAMPLES: Tantalum, polyester

H. Connection arrangement--Configuration of wire leads; how capacitor is to be mounted

EXAMPLES: Solder leads, solder lugs, terminal

XV. Instruments which test capacitors

A. Multimeter

(NOTE: A multimeter can be used for a quick check without the use of larger test equipment; however this method is not as accurate as the use of the capacitor analyzer.)

B. Capacitor analyzer

(NOTE: A more accurate reading than that given by the multimeter can be taken by the capacitor analyzer; also the capacitor can be given an insulation resistance and leakage current test.)

Capacitor Construction

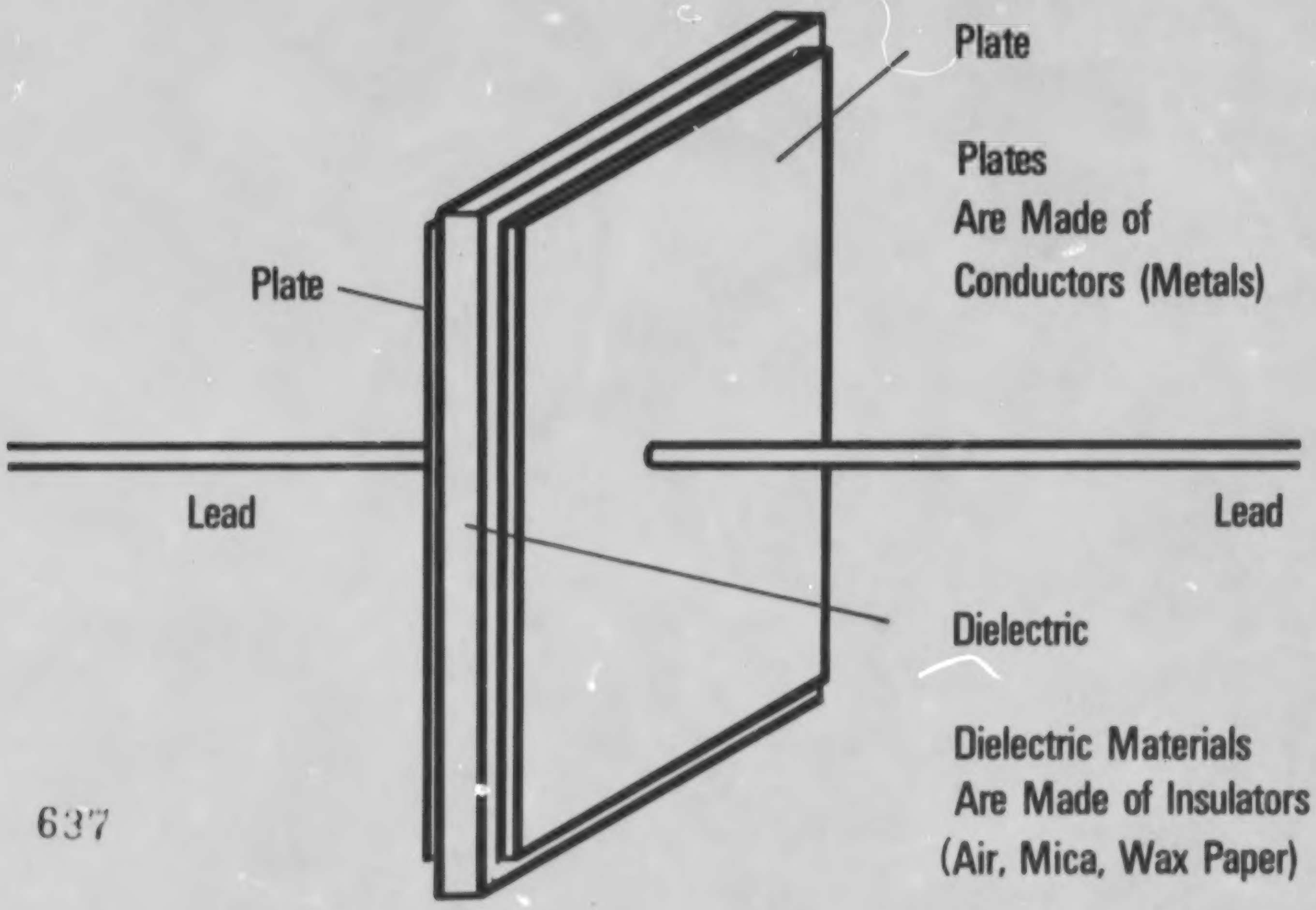


Plate
Plate
Lead
Lead
Dielectric

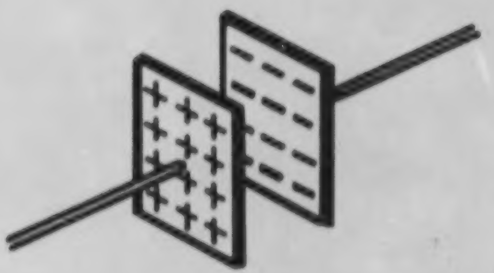
Plates
Are Made of
Conductors (Metals)

Dielectric Materials
Are Made of Insulators
(Air, Mica, Wax Paper)

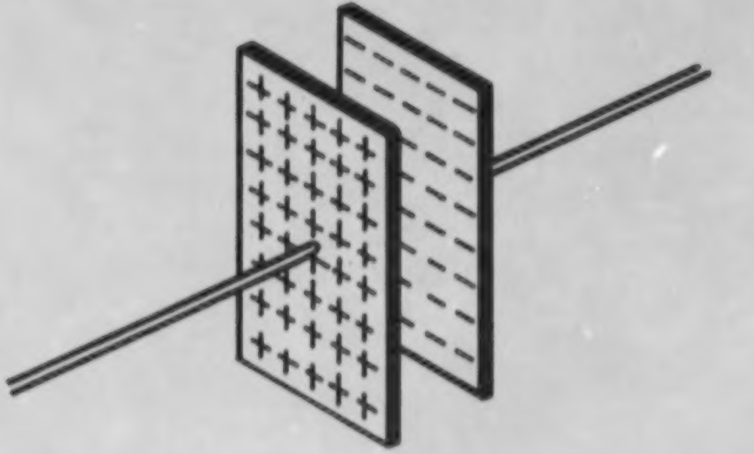
TM #1

IIEE - 67-E

Plate Area



Larger Plates Hold More Electrons

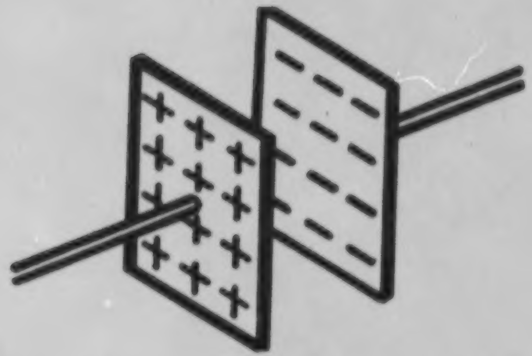


Increased Plate Area Increases Capacitance

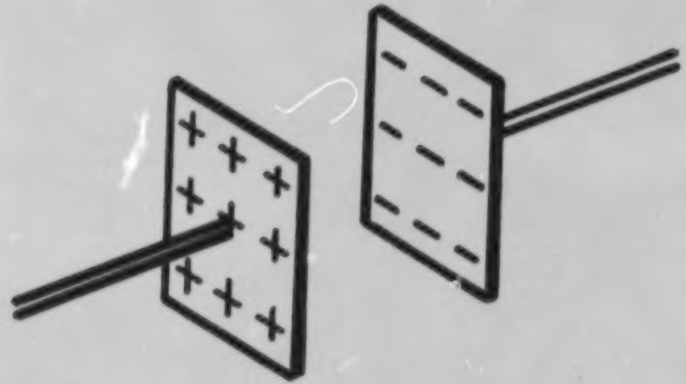
TM #2

IIEE - 69-E

Plate Distance



The Distance Between Two Charges Determines Their Effect on One Another



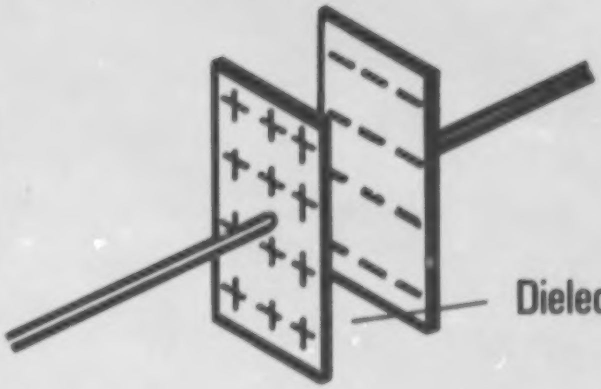
Increasing Distance Between the Plates Decreases Capacitance

TM #3

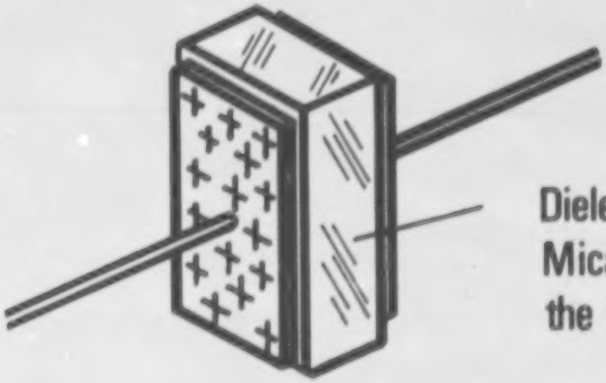
IIEE-71-E

Effect of the Dielectric

Typical Dielectrics		
Type	Constant	Breakdown
Air	1.0	-----
Mica	5.4	5000 V/Mil
Teflon	2.1	1500 V/Mil
Paper	3.0	200 V/Mil



Dielectrical Material is Air

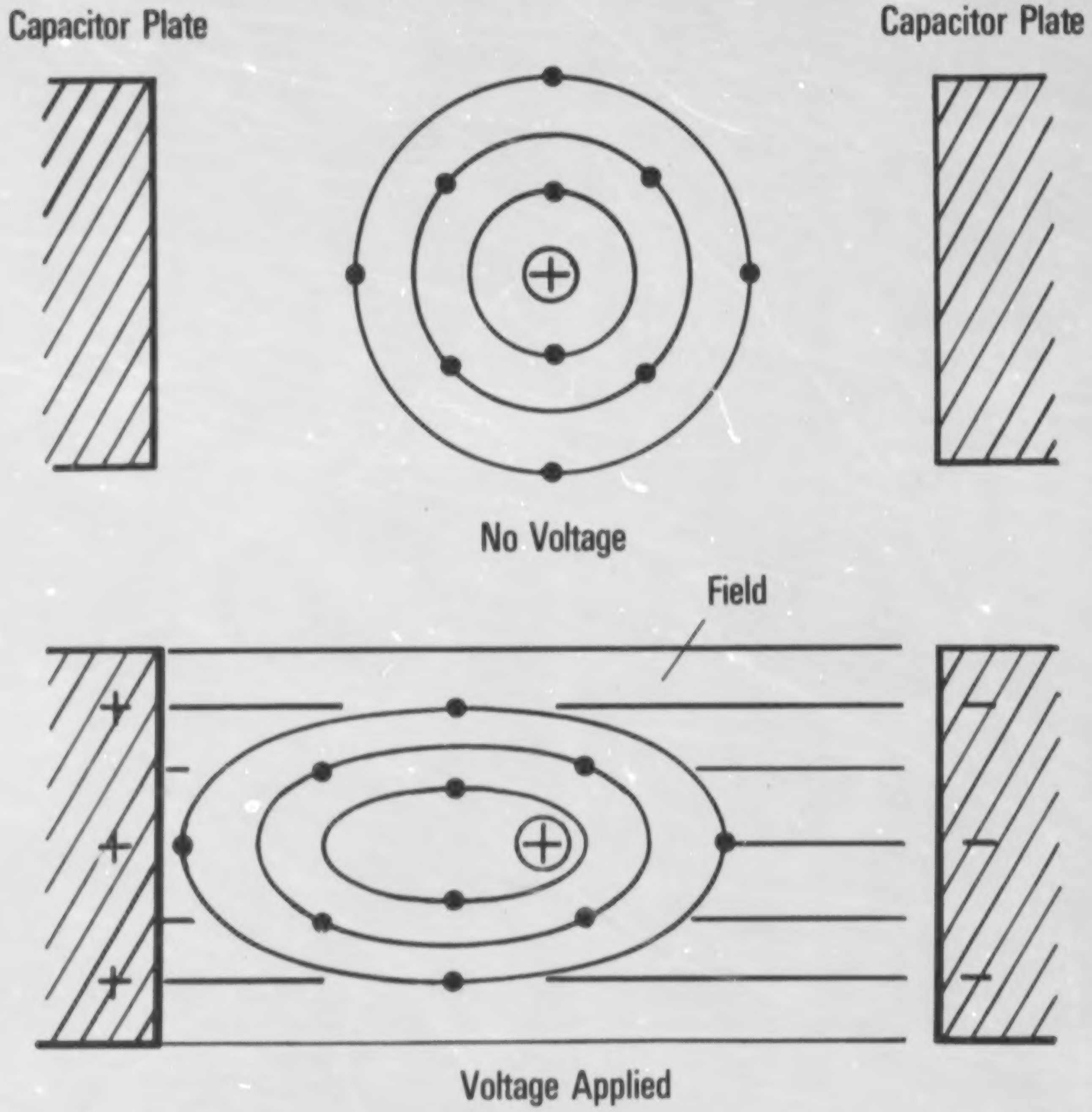


Dielectrical Material is Mica
Mica Dielectric Increases
the Capacitance

Changing the Dielectric Material Changes the Capacitance

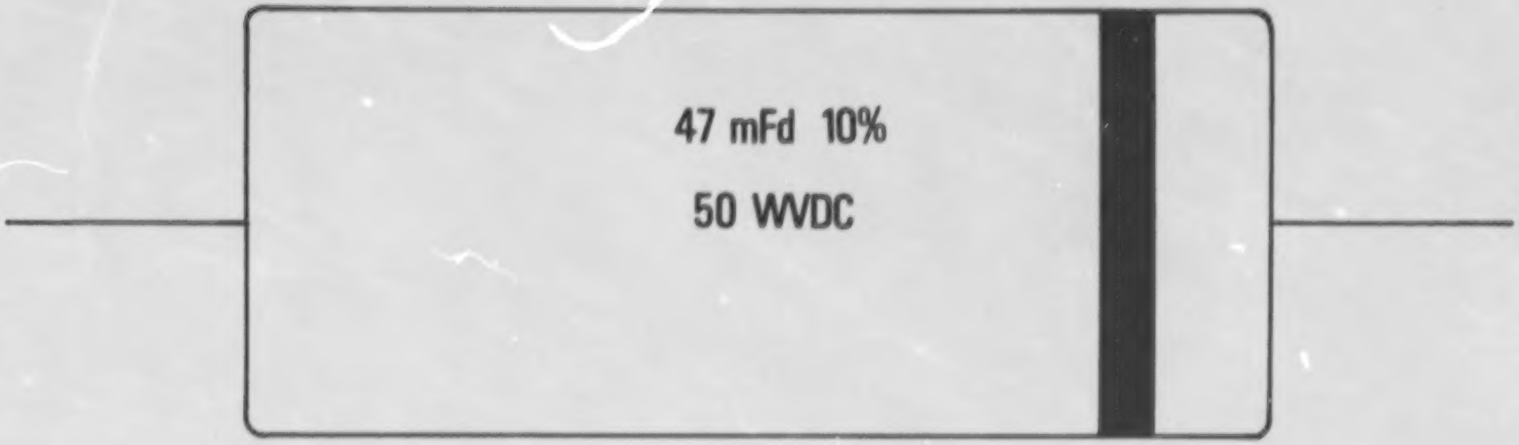
IIEE · 75-E

Electric Field Effect on Capacitors


Capacitor Plate
Capacitor Plate
No Voltage
Field
Voltage Applied

TM #5

Capacitor Specifications


47 mFd 10%
50 WVDC

CAPACITORS
UNIT II

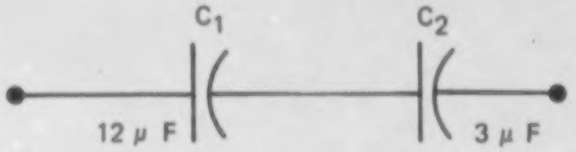
ASSIGNMENT SHEET #1--CALCULATE THE EQUIVALENT CAPACITANCE OF CAPACITORS IN SERIES

NAME ______________________________ SCORE ______________________

Equivalent capacitance of series capacitors is less than the smallest capacitor. Calculate the equivalent capacitance of the series capacitors in Figures 26-29 below.

A.

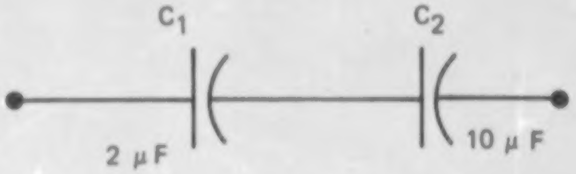
FIGURE 26


C_1
C_2
12 μ F
3 μ F

C_e = ______________________________

B.

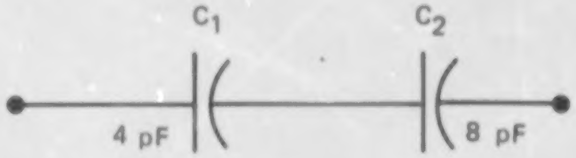
FIGURE 27


C_1
C_2
2 μ F
10 μ F

C_e = ______________________________

C.

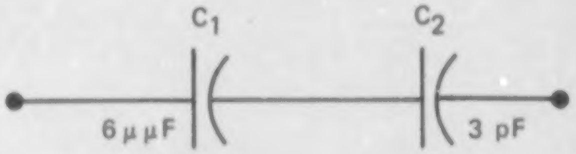
FIGURE 28


C_1
C_2
4 pF
8 pF

C_e = ______________________________

D.

FIGURE 29


C_1
C_2
6 μμF
3 pF

C_e = ______________________________

CAPACITORS
UNIT II

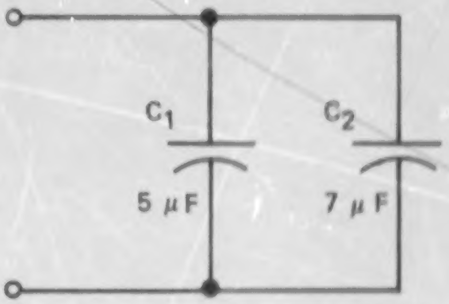
ASSIGNMENT SHEET #2--CALCULATE THE EQUIVALENT CAPACITANCE OF CAPACITORS IN PARALLEL

NAME ______________________ SCORE ______________

To increase capacitance, capacitors can be added in parallel. Many power supply circuits have several parallel capacitors. Calculate the capacitance of the parallel capacitors in Figures 30-33 below.

A.

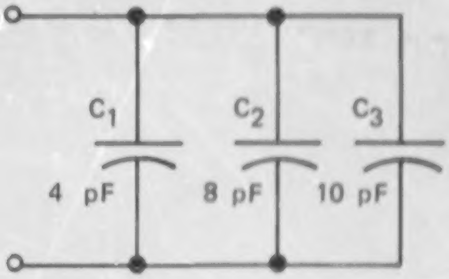
FIGURE 30


C_1
C_2
5 μF
7 μF

C_e = ______________________

B.

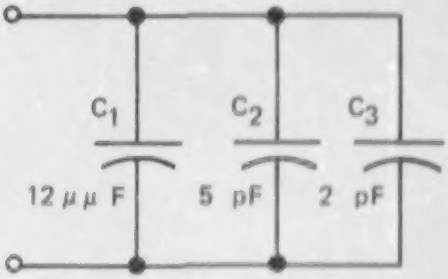
FIGURE 31


C_1
C_2
C_3
4 pF
8 pF
10 pF

C_e = ______________________

C.

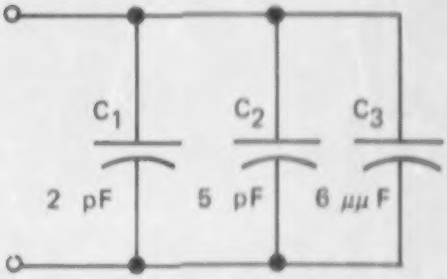
FIGURE 32


C_1
C_2
C_3
12 μμ F
5 pF
2 pF

C_e = ______________________

D.

FIGURE 33


C_1
C_2
C_3
2 pF
5 pF
6 μμ F

C_e = ______________________

CAPACITORS
UNIT II

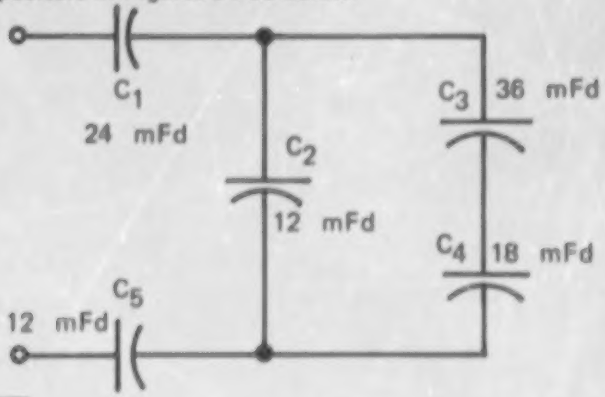
ASSIGNMENT SHEET #3--CALCULATE THE EQUIVALENT CAPACITANCE OF CAPACITORS IN SERIES-PARALLEL

NAME ______________________________ SCORE ____________________

Capacitors may be used in many configurations. You will often see them in series-parallel. Calculate the capacitance of the series-parallel capacitors in Figures 34-36 below.

A.

FIGURE 34

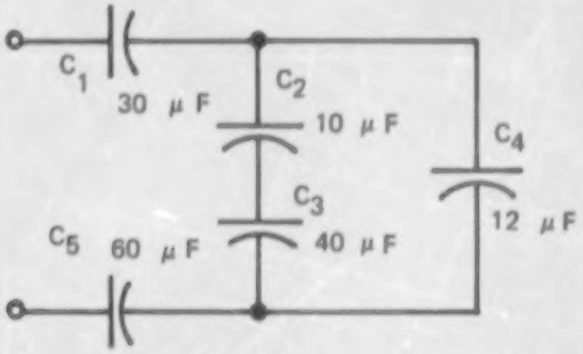


C_1
24 mFd
C_2
12 mFd
C_3 36 mFd
C_4 18 mFd
C_5
12 mFd

C_e = ______________________________

B.

FIGURE 35

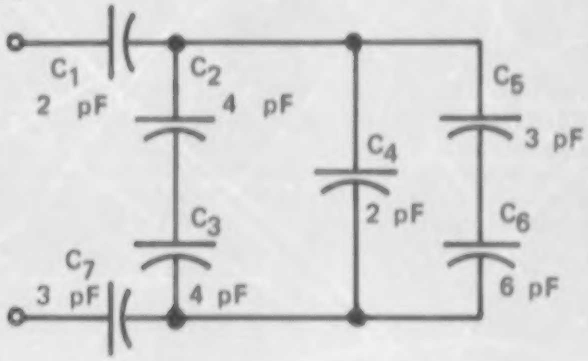


C_1
30 μ F
C_2
10 μ F
C_3
40 μ F
C_4
12 μ F
C_5 60 μ F

C_e = ______________________________

C.

FIGURE 36



C_1
2 pF
C_2
4 pF
C_3
4 pF
C_4
2 pF
C_5
3 pF
C_6
6 pF
C_7
3 pF

C_e = ______________________________

CAPACITORS
UNIT II

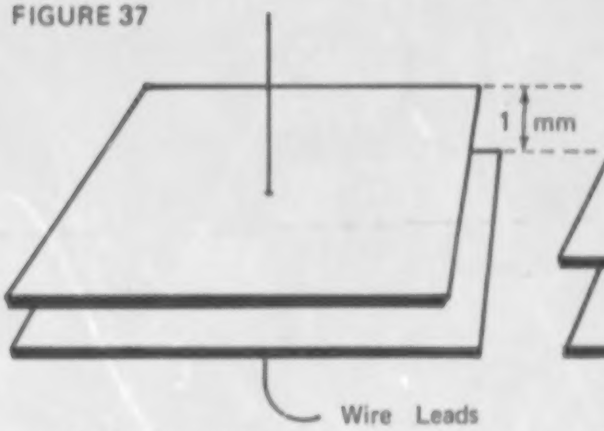
ASSIGNMENT SHEET #4--STATE HOW CAPACITOR PARAMETERS AFFECT CAPACITANCE

NAME ______________________________ SCORE ________________

Capacitance is affected primarily by the size of the plates, distance between the plates, and substance between the plates. For Figures 37-42 below, state whether capacitance will increase or decrease from the original value.

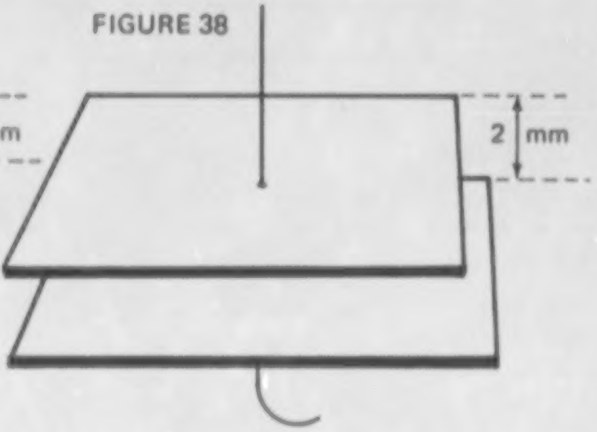
A. ______________________________

FIGURE 37



Original parallel capacitor

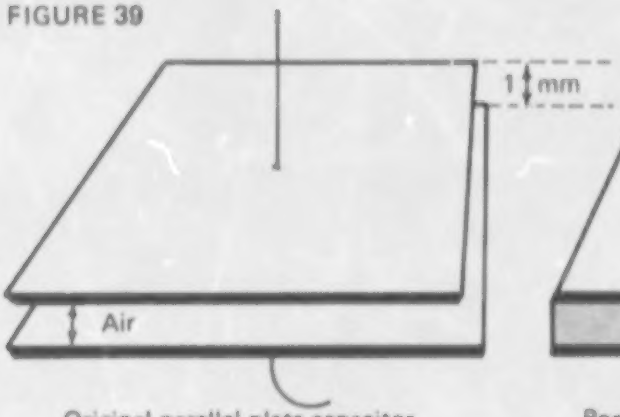
FIGURE 38



Plates moved apart

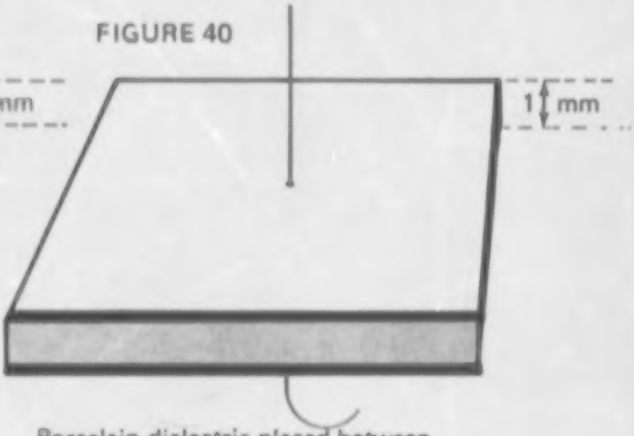
B. ______________________________

FIGURE 39



Original parallel plate capacitor

FIGURE 40

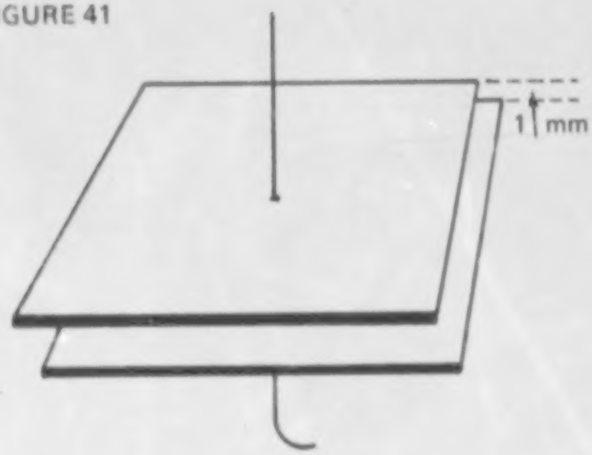


Porcelain dielectric placed between plates

ASSIGNMENT SHEET #4

C. ______________________________

FIGURE 41



Original parallel plate capacitor

FIGURE 42

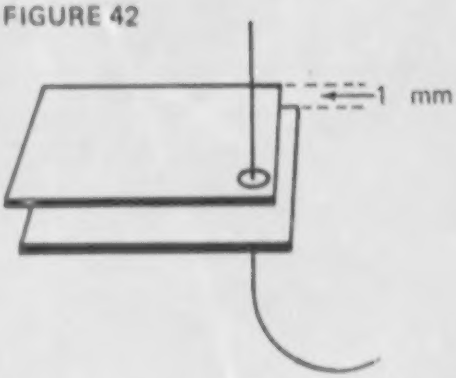


Plate size cut to 1/4 area

CAPACITORS
UNIT II

ASSIGNMENT SHEET #5--WRITE EXAMPLES OF THE EIGHT SPECIFICATIONS THAT DESCRIBE A CAPACITOR

NAME ______________________________ SCORE ____________________

Unless a replacement capacitor is adequately described, the wrong component may be received. Write an example for each of the specifications given below.

A. Capacitance-- ______________________________

B. Tolerance-- ______________________________

C. Working volts-- ______________________________

D. Polarity-- ______________________________

E. Structure-- ______________________________

F. Function-- ______________________________

G. Composition-- ______________________________

H. Connection arrangement-- ______________________________

CAPACITORS
UNIT II

ASSIGNMENT SHEET #6--SPECIFY REPLACEMENTS FOR CERTAIN CAPACITORS

NAME ______________________ SCORE ______________

By observing the appearance of capacitors, noting the information printed on them, and checking conditions under which they operate, a technician can usually adequately specify a replacement where no other sources of information are available. Ask your instructor to provide you with several capacitors. In the space below, describe the capacitors as fully as you can. Check your results with your instructor. It may be possible to determine all eight specifications.

Capacitor #1

____

____

____

Capacitor #2

____

____

____

Capacitor #3

____

____

____

Capacitor #4

____

____

____

CAPACITORS
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 2.4 μF

B. 1.67 μF

C. 2.67 pF or 2.67 μμF

D. 2 μμF or 2 pF

Assignment Sheet #2

A. 12 μF

B. 22 pF or 22 μμF

C. 19 pF or 19 μμF

D. 13 pF or 13 μμF

Assignment Sheet #3

A. 6 μF

B. 10 μF

C. 1 pF or 1 μμF

Assignment Sheet #4

A. Decreases

B. Increases

C. Decreases

Assignment Sheet #5

A. Number followed by μF, μμF, pF, or some variation of those abbreviations

B. 10%, 20%, or a similar expression of tolerance

C. Number followed by WV, or WVDC

D. None or electrolytic

ANSWERS TO ASSIGNMENT SHEETS

E. Answer may be any one of the following: Tubular, disk, rectangular

F. Fixed or variable

G. Answer may be any of the following: Mica, paper, oil

H. Solder leads, terminal posts, solder lugs

Assignment Sheet #6

Answers evaluated to satisfaction of instructor

CAPACITORS
UNIT II

JOB SHEET #1--OBSERVE THE EFFECTS OF A CAPACITOR ON BOTH AC AND DC VOLTAGE

I. Equipment and materials

  A. Oscilloscope

  B. Function analyzer

  C. DC generator

  D. Resistor--Selected by instructor

  E. Capacitor--Selected by instructor

  F. Circuit board

  G. Scope probe

  H. Test leads

II. Procedure

  A. Set up test equipment

  B. Turn on equipment

  C. Check to see that power supply and function analyzer voltage controls are fully counterclockwise

  D. Hook up designated components on circuit board

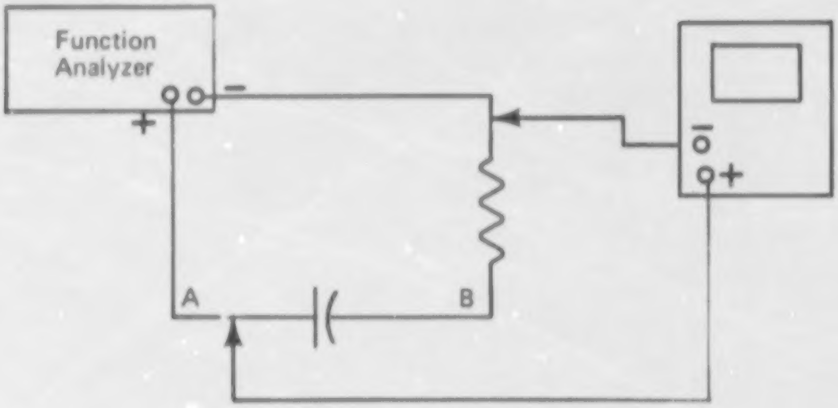
  (NOTE: Use a resistor, capacitor, and frequency with compatible values and times.)

  EXAMPLE: A 1500 ohm resistor, a .002 μF capacitor, and a frequency of 333 kHZ

JOB SHEET #1

E. Hook up circuit as designated in Figure 43

FIGURE 43



F. Turn the function analyzer amplitude up to read 20 VAC on the oscilloscope

G. Move the oscilloscope test lead to position "B," between the capacitor and the resistor

H. Read the voltage

I. Record your answer

Voltage = ____

J. Remove function analyzer from circuit

K. Hook up DC power supply with oscilloscope connected to position "A" and ground

L. Turn up the DC power supply voltage to 20 VDC as indicated on the oscilloscope

M. Move oscilloscope lead to position "B," between the capacitor and the resistor

N. Read the voltage

O. Record your answer

Voltage = ____

P. Turn off test equipment

JOB SHEET #1

Q. Are the voltages all the same? If not, why not?

____

____

____

(NOTE: Show your results to the instructor.)

R. Put equipment and materials away

CAPACITORS
UNIT II

JOB SHEET #2--USE A MULTIMETER TO CHECK CAPACITORS

I. Equipment and materials

- A. Multimeter
- B. Capacitors--6 each of various sizes

II. Procedure

- A. Set up multimeter to measure resistance
- B. Set range switch to highest position
- C. Connect multimeter to capacitor while observing meter indication
- D. Reverse meter leads to capacitor while observing meter indication
- E. Record indications in the spaces provided, repeating Steps C through E for all capacitors

Capacitor #1 ____

____

Capacitor #2 ____

____

Capacitor #3 ____

____

Capacitor #4 ____

____

Capacitor #5 ____

____

Capacitor #6 ____

____

(NOTE: Discuss your results with the instructor.)

- G. Put equipment and materials away

CAPACITORS
UNIT II

JOB SHEET #3--OPERATE A CAPACITOR TESTER

I. Equipment and materials

   A. Capacitor tester

   B. Capacitors--One electrolytic, one electrostatic

   C. Instruction booklet for capacitor tester, unless operating procedure is printed on the case of the tester

II. Procedure

   A. Review the operating procedure for the capacitor tester as given to you in the instruction booklet or as printed on the case of the tester

   B. If an electrolytic capacitor is being tested, determine which end of the capacitor is the positive end

   C. Measure the capacitance of the electrolytic capacitor, following directions given with the capacitor tester

   D. Record the reading

   Capacitance = ______________________________

   E. Measure the leakage current, following directions given with the capacitor tester

   F. Record the reading

   Leakage current = ______________________________

   G. Remove the electrolytic capacitor from the tester

   H. Connect the electrostatic capacitor to the tester

   I. Measure the capacitance, following directions given with the capacitor tester

   J. Record the reading

   Capacitance = ______________________________

   K. Measure the insulation resistance, following directions given with the capacitor tester

   L. Record the reading

   Insulation resistance = ______________________________

JOB SHEET #3

M. Compare your readings to those listed on the capacitor under test

(NOTE: Show your results to the instructor.)

N. Put equipment and materials away

CAPACITORS
UNIT II

TEST

NAME ______________________________ SCORE ____________________

1. Match terms associated with capacitors to their correct definitons. Write the correct numbers in the blanks.

_____a. Circuit of two-lead components connected end-to-end

_____b. Path for or the action of electricity passing through unintentional conducting materials; usually results in excessive current flow that may cause damage

_____c. Voltage wave as a representation of voltage changing with time

_____d. Undesirable current flow between capacitor plates due to inability of dielectric material to restrict that flow

_____e. Undesirable electronic interference

_____f. Substance that prohibits flow of electricity

_____g. Movement of electricity from one place to another

_____h. Circuit or device that produces electronic waves

_____i. Insulating substance between plates of capacitor

_____j. Instrument that produces different shapes of electronic waveforms at various frequencies

_____k. Circuit of two-lead components connected side-by-side

_____l. Instrument that measures capacitance and leakage current

_____m. Instrument that measures electrical resistance

_____n. Capacitor that must be connected in only one direction

1. Dielectric
2. Waveform
3. Parallel
4. Insulation
5. Series
6. Capacitor tester
7. Oscillator
8. Short-circuit
9. Power transfer
10. Function analyzer
11. Noise
12. Leakage current
13. Electrolytic capacitor
14. Ohmmeter

TEST

_____o. Disconnection, or broken conductor which restricts electricity from flowing

_____p. Unit of capacitance equal to one-millionth of a farad; 10^{-6} farad

_____q. Measure of capacitance

_____r. Unit of capacitance equal to one-trillionth of a farad; 10^{-12}

_____s. Microcircuit package with two rows of seven vertical leads that are easily inserted into an etched circuit board

15. Farad
16. Open circuit
17. Microfarad
18. Micromicrofarad
19. Dual in-line package

2. Match abbreviations associated with capacitors to their correct definitons. Write the correct numbers in the blanks.

_____a. Direct current

_____b. Micromicrofarads

_____c. Volts

_____d. Capacitance

_____e. Working volts

_____f. Equivalent capacitance

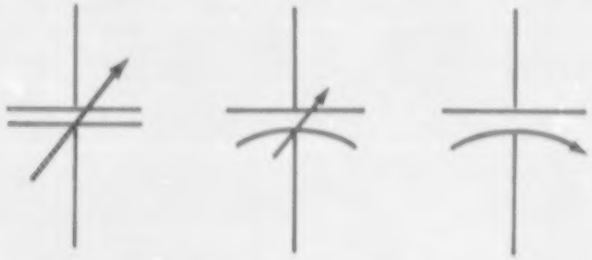
_____g. Picofarad

_____h. Dual in-line package

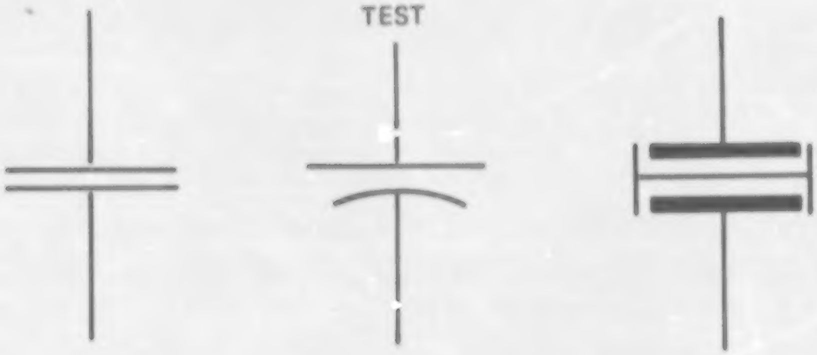
_____i. Microfarad

1. mmF, mmFd, or μμF
2. pf, pFd
3. C
4. C_e
5. DC
6. mF, mFd, or μF
7. DIP
8. WV
9. V

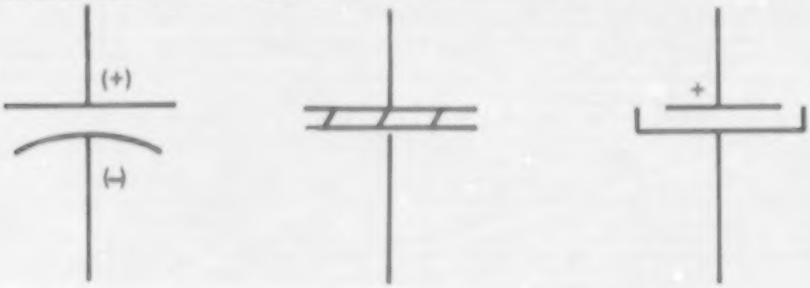
3. Label capacitor schematic symbols. Write the correct answers in the blanks below each symbol.



a. ____



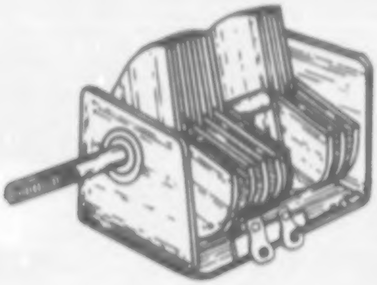
b. ______________________________



c. ______________________________

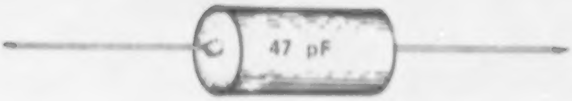
4. Identify common capacitor structures. Write the correct names from the list below in the blanks.

Tubular	Rectangular or flat pack
Disk or disk-shaped	Dual in-line package
Parallel plates	Aluminum can capacitor

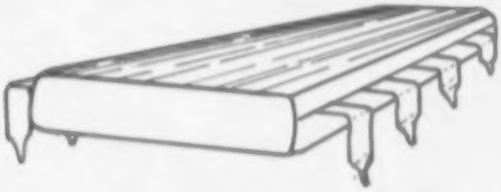


a. ______________________________

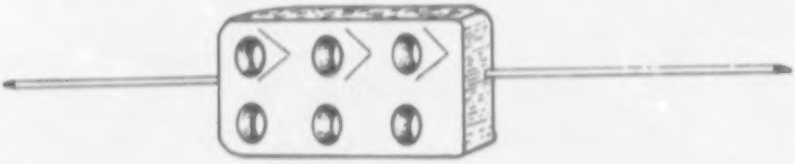
TEST



b. ____________________

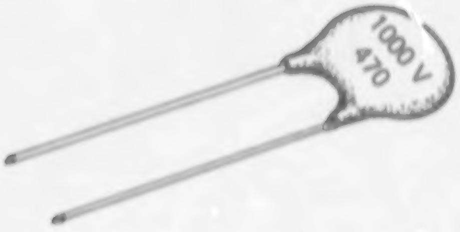


c. ____________________

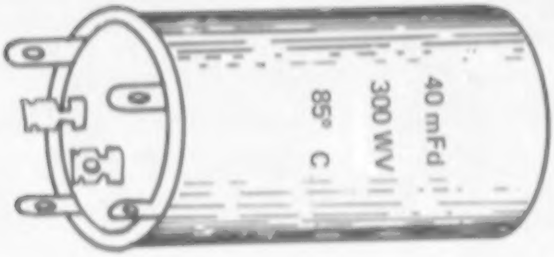


d. ____________________

TEST

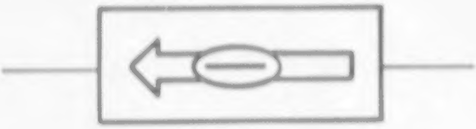


e. ______________________________


40 mFd
300 WV
85° C

f. ______________________________

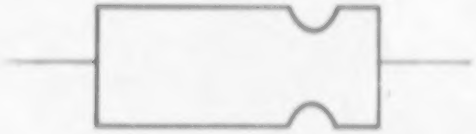
5. Label common capacitor markings. Write the correct names in the spaces below each marking.



a. ______________________________

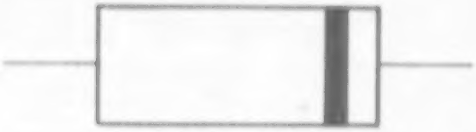
____

TEST



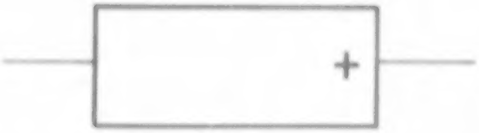
b. ______________________________

____



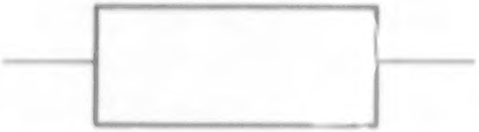
c. ______________________________

____



d. ______________________________

____

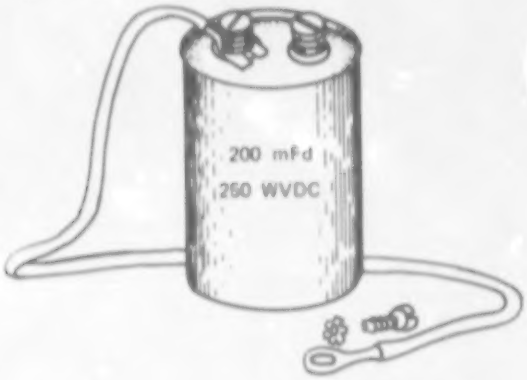


e. ______________________________

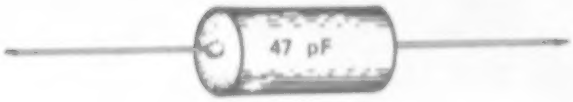
____

TEST

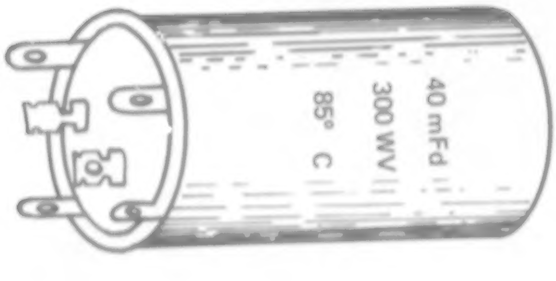
6. Label common capacitor connection arrangements. Write the correct names in the blanks below each capacitor.


200 mFd
250 WVDC

a. ______________________________



b. ______________________________


40 mFd
300 WV
85° C

c. ______________________________

TEST

7. List capacitor applications in electronics.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

8. Distinguish among capacitor parameters. Write in the correct blanks an "A" for those characteristics denoting the area of plates, a "D" for those characteristics denoting the distance between plates, and a "DC" for those characteristics denoting the dielectric constant.

______a. Plates are assembled very close together to make capacitors as small as possible

______b. Close plates require good insulation to keep electricity from short-circuiting across

______c. Unlike resistors, capacitors of high capacitance are necessarily large

______d. Capacitance is directly related to plate area

______e. If plate area is increased, capacitance is increased

______f. Capacitance decreases as plates are spaced apart

______g. Insulating material between capacitor plates can increase capacitance value

9. List below three characteristics of capacitors.

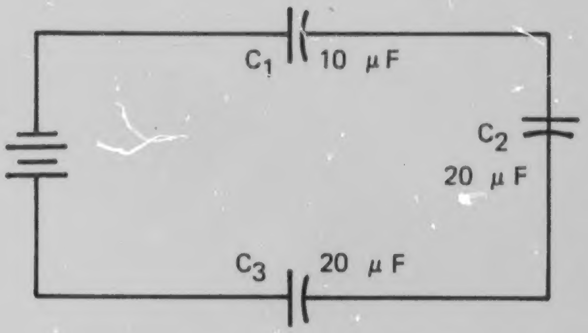
a. ____

b. ____

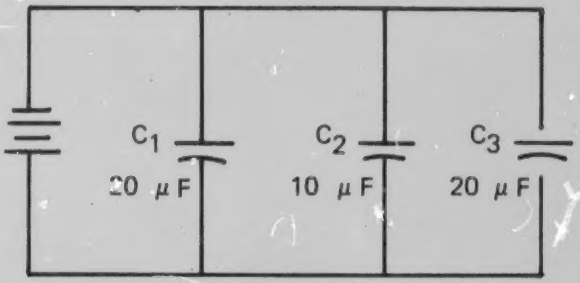
c. ____

TEST

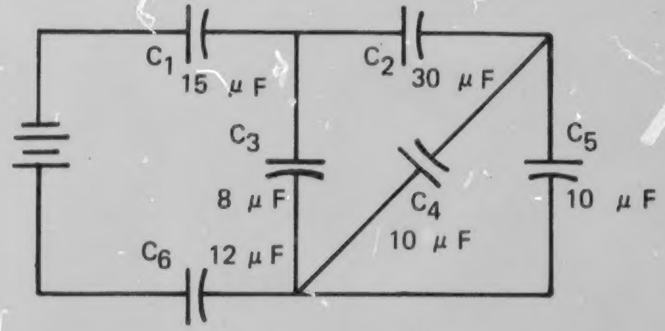
10. Calculate equivalent capacitance in the following circuits. Write the values in the spaces provided.


C_1
10 μF
C_2
20 μF
C_3
20 μF

a. ______________________


C_1
20 μF
C_2
10 μF
C_3
20 μF

b. ______________________


C_1
15 μF
C_2
30 μF
C_3
8 μF
C_4
10 μF
C_5
10 μF
C_6
12 μF

c. ______________________

11. Describe dangers presented by capacitors.

____

____

____

TEST

12. Discuss precautions to take when working with capacitors.

TEST

13. Match types of capacitor failures to correct detection techniques. Write the correct numbers in the blanks.

______a. Requires capacitor tester in most instances to detect; ohmmeter will not deflect and then slowly return to the open or infinite resistance reading as is the usual reaction

______b. Easily detected with an ohmmeter; meter will indicate a low resistance value

______c. Requires a capacitor tester to verify; timing, waveform, or frequency of circuit may be abnormal

______d. Requires capacitor tester to verify; ohmmeter may indicate some resistance between terminals

1. Excessive leakage current
2. Change in capacitance
3. Open circuit
4. Short circuit

14. Match capacitor specifications to their correct descriptions. Write the correct numbers in the blanks.

______a. Shape of capacitor

______b. Precision with which capacitor is manufactured

______c. Direction which certain types of capacitors should be connected in a circuit

______d. Configuration of the wire leads; how capacitor is to be mounted

______e. Ability to store electricity: measured in units called *farads* and *fractions of farads*

______f. Material of capacitor

______g. Application of capacitor

______h. Maximum DC voltage that may be applied to a capacitor without damaging the capacitor

1. Connection arrangement
2. Tolerance
3. Structure
4. Composition
5. Function
6. Capacitance
7. Polarity
8. Working volts

15. List instruments used to test capacitors.

a. ____

b. ____

TEST

(NOTE: Test questions 16-24 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

16. Calculate the equivalent capacitance of capacitors in series.
17. Calculate the equivalent capacitance of capacitors in parallel.
18. Calculate the equivalent capacitance of capacitors in series-parallel.
19. State how capacitor parameters affect capacitance.
20. Write examples of the eight specifications that describe a capacitor.
21. Specify replacements for certain capacitors.
22. Demonstrate the ability to
    a. Observe the effects of a capacitor on both AC and DC voltage.
    b. Use a multimeter to check capacitors.
    c. Operate a capacitor tester.

CAPACITORS
UNIT II

ANSWERS TO TEST

1.	a.	5	k.	3
	b.	8	l.	6
	c.	2	m.	14
	d.	12	n.	13
	e.	11	o.	16
	f.	4	p.	17
	g.	9	q.	15
	h.	7	r.	18
	i.	1	s.	19
	j.	10		

2.	a.	5	f.	4
	b.	1	g.	2
	c.	9	h.	7
	d.	3	i.	6
	e.	8		

3. a. Variable capacitor
   b. Non-polar capacitor (electrostatic)
   c. Polar capacitor (electrolytic)

4. a. Parallel plates
   b. Tubular
   c. Dual in-line package
   d. Rectangular or flat pack
   e. Disk or disk-shaped
   f. Aluminum can

ANSWERS TO TEST

5. a. Arrow points toward negative end of polar capacitor

b. Crease in capacitor represents the positive end of polar capacitor

c. Ring around one end of capacitor indicates the positive end of polar capacitor

d. Plus sign on one end of capacitor indicates the positive end of polar capacitor

e. No markings indicate that the capacitor is non-polar

6. a. Terminal posts

b. Soldier leads

c. Soldier lugs

7. a. Filters

b. Oscillators

c. Tuners

d. Wave shaping

8. a. D

b. D

c. A

d. A

e. A

f. D

g. DC

9. a. Block direct current (DC)

b. Permit flow of alternating current (AC)

c. Store electrical energy

10. a. 5 μF

b. 50 μF

c. 5 μF

ANSWERS TO TEST

11. Answer should include
    a. Electrical shock
        1. Large capacitors can store enough energy to deliver a fatal electric shock
        2. Small capacitors can cause electrical shocks resulting in serious injury from involuntary muscle reactions
    b. Explosions
        1. Voltage higher than a capacitor's rated working voltage can result in a capacitor explosion
        2. Rapid charge or discharge of a capacitor involving too sudden a power transfer can result in a capacitor explosion
        3. An electrolytic capacitor connected in the wrong direction in a circuit is more likely to fail or explode at high voltage
12. Answer should include
    a. Discharging capacitors to avoid shock
        1. Large capacitors should be discharged through a resistor in order to prevent a large electric arc or sudden power transfer
        2. Small capacitors can be discharged directly
        3. Bleeder resistors are designed in some circuits to automatically discharge capacitor when power is turned off, but may require a moment to discharge capacitor completely
    b. Installing capacitors correctly
        1. Check capacitors for polarity markings before installing them in circuit
        2. Make certain capacitors working voltage is sufficient for application
13. a. 3
    b. 4
    c. 2
    d. 1
14. a. 3
    b. 2
    c. 7
    d. 1
    e. 6
    f. 4
    g. 5
    h. 8

ANSWERS TO TEST

15. a. Multimeter
    b. Capacitor analyzer
16. Evaluated to satisfaction of instructor
17. Evaluated to satisfaction of instructor
18. Evaluated to satisfaction of instructor
19. Evaluated to satisfaction of instructor
20. Evaluated to satisfaction of instructor
21. Evaluated to satisfaction of instructor
22. Performance skills evaluated to satisfaction of instructor

INDUCTORS
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to calculate series, parallel, and series-parallel inductance. This knowledge will be shown by completing assignment sheets, job sheet, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with inductors to their correct definitions.
2. Match abbreviations associated with inductors to their correct definitions.
3. Identify schematic symbols associated with inductors.
4. List basic-core types of inductors.
5. List factors that determine inductance.
6. Calculate total inductance in a series circuit.
7. Calculate total inductance in a parallel circuit.
8. Calculate total inductance in a series-parallel circuit.
9. Discuss Lenz's Law as it applies to inductors.
10. Explain self-inductance.
11. Explain mutual inductance.
12. State methods of increasing the coefficient of coupling.
13. Demonstrate the ability to operate an inductance meter.

INDUCTORS
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Provide students with objective sheets.

  B. Provide students with information, assignment, and job sheets.

  C. Make transparencies.

  D. Discuss unit and specific objectives.

  E. Discuss information sheet.

  F. Demonstrate and discuss procedures outlined in assignment and job sheets.

  G. Demonstrate mutual inductance by making two coils.

    1. Wind wire (AWG #20 or above) around two iron bolts, making two separate coils.

    2. Place coils in a perpendicular position.

    3. Apply an AC signal to one coil and measure the output of the second coil.

    4. Place coils in a parallel position and repeat step 3.

    5. Explain the different outputs of the coils to the students.

  H. Give test.

II. Instructional materials

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM #1--Factors that Determine Inductance

    2. TM #2--Factors that Determine Inductance (Continued)

    3. TM #3--Inductor Build-up

    4. TM #4--Coefficient of Coupling

SUGGESTED ACTIVITIES

D. Assignment sheets

1. Assignment Sheet #1--Calculate Total Inductance in a Series Inductive Circuit
2. Assignment Sheet #2--Calculate Total Inductance in a Parallel Inductive Circuit
3. Assignment Sheet #3--Calculate Total Inductance in a Series-Parallel Inductive Circuit

E. Answers to assignment sheets

F. Job Sheet #1--Operate an Inductance Tester

G. Test

H. Answers to test

III. Unit references

A. Grob, Bernard. *Basic Electronics*. 4th ed. New York: McGraw-Hill Book Company, 1977.

B. Seippel, Robert G. *Alternating Current Circuit Analysis*. Chicago: American Technical Society, 1975.

C. Shrader, Robert L. *Electronic Communication*. 3rd ed. New York: McGraw-Hill Book Company, 1975.

INDUCTORS
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Inductor--Component of an electrical circuit that produces inductance

B. Inductance--Physical property of an inductor that opposes any change in current flow

C. Induction--Production of an electric charge or magnetic field in a substance by an electrical source, magnet, or magnetic field

D. Self-inductance--Conductor's ability to induce voltage in itself when current changes

E. Electromotive force--Force or voltage that causes current flow through an inductor

F. Counter electromotive force--Voltage developed in an inductor which is opposite that of the applied voltage at every instant

G. Coil--Number of turns of wire that is wound around an iron core or form of insulating material

(NOTE: *Coil* often is referred to as an inductor.)

H. Coefficient of coupling--The percentage of flux between linking coils; expressed as a decimal

I. Mutual inductance--Linking lines of force from one current-carrying conductor to another

J. Choke--Inductance used to impede AC flow

K. Leakage flux--Any magnetic lines that do not link two coils

L. Henry--Unit of measurement for inductance or mutual inductance

II. Abbreviations associated with inductors

A. **L**--Inductance, inductor

B. **L_e**--Equivalent inductance

C. **DC**--Direct current

D. **AC**--Alternating current

E. **K**--Coefficient of coupling

F. **L_m**--Mutual inductance

G. μ--Permeability

INFORMATION SHEET

H. **H**--Henry

I. **L_t**--Total inductance

J. **emf**--Electromotive force

K. **Cemf**--Counter electromotive force

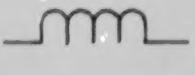
L. **mH**--Millihenry

M. **μH**--Microhenry

III. Schematic symbols associated with inductors (Figures 1-4)

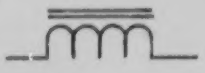
A. Air core inductor

FIGURE 1



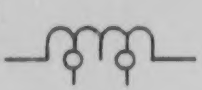
B. Iron core inductor

FIGURE 2



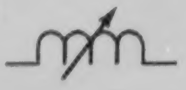
C. Tapped inductor

FIGURE 3



D. Variable inductor

FIGURE 4



IV. Basic-core types of inductors

A. Air

(NOTE: Air core coils have a low *K* or coefficient of coupling, with *K* equal to .05 to .3.)

B. Iron

(NOTE: Iron coils have a high *K* or coefficient of coupling, with *K* equal to 1.)

INFORMATION SHEET

V. Factors that determine inductance (Transparencies #1 and #2)

A. Number of turns of coil

(NOTE: More turns of coil allow more voltage to be induced. Double the number of turns, and inductance is increased four times.)

B. Core diameter

(NOTE: Increasing the diameter of turns increases the inductance. Inductance increases in proportion to the area squared, thus allowing more space for the magnetic field.)

C. Core length

(NOTE: A longer core with equal turns of coil will decrease inductance.)

D. Core permeability

(NOTE: Different core materials have various permeability levels affecting inductance.)

E. Number of coil layers

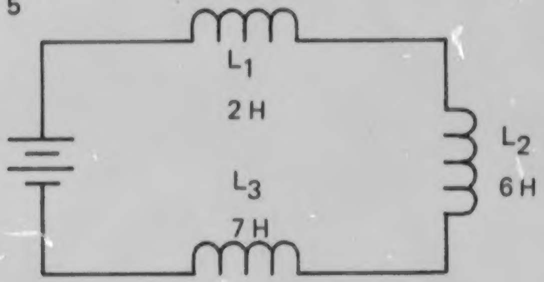
(NOTE: More layers will increase inductance.)

VI. Calculating total inductance in a series circuit (Assignment Sheet #1; Figure 5)-- Use the formula, $L_t = L_1 + L_2 + L_3 \ldots$

(NOTE: Inductors in series are treated as resistors in series and are measured in henries.)

EXAMPLE:

FIGURE 5



$$L_t = L_1 + L_2 + L_3 \ldots$$
$$= 2H + 6H + 7H$$
$$= 15\ H$$

INFORMATION SHEET

VII. Calculating total inductance in a parallel circuit (Assignment Sheet #2; Figure 6)

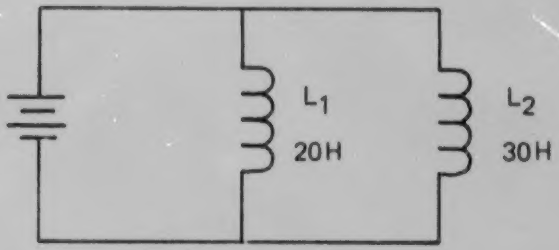
--Use the formula

$$L_t = \frac{L_1 \times L_2}{L_1 + L_2} = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} \ldots} = \frac{L}{N}$$

(NOTE: Inductors in parallel are treated as resistors in parallel.)

EXAMPLE:

FIGURE 6



$$L_t = \frac{L_1 \times L_2}{L_1 + L_2}$$

$$= \frac{20\text{ H} \times 30\text{ H}}{20\text{ H} + 30\text{ H}}$$

$$= \frac{600\text{ H}}{50\text{ H}}$$

$$= 12\text{ H}$$

VIII. Calculating total inductance in a series-parallel circuit (Assignment Sheet #3; Figure 7)

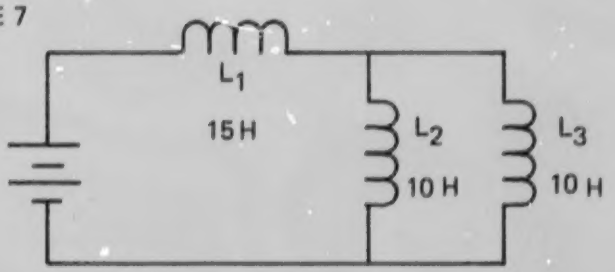
(NOTE: Series-parallel inductive circuits are also calculated as series-parallel resistive circuits.)

INFORMATION SHEET

A. Calculate the equivalent resistance of L_2 and L_3

EXAMPLE:

FIGURE 7



(NOTE: Since total current flows through series inductors, and current divides through parallel inductors L_2 and L_3, the equivalent inductance of L_2 and L_3 must be calculated first.)

If L_2 and L_3 are equal in inductance, the following formula may be used

$L_e = \frac{L}{N}$

L = Inductance
N = Number of inductors

$= \frac{10H}{2}$

$= 5H$

B. Calculate total inductance

EXAMPLE: $L_t = L_1 + L_e$ (using example in Figure 7)

$= 15H + 5H$

$= 20H$

IX. Lenz's Law as it applies to inductors

A. Induced voltage builds a field around the conductor (Transparency #3)

B. Shape of the inductor causes the field of one coil to be in opposition to the field of an adjacent coil, thus causing an opposition to current flow

(NOTE: This opposing field is referred to as a *counter electromotive force* and is abbreviated *Cemf.*)

C. Counter electromotive force causes current to begin building slowly

INFORMATION SHEET

D. Counter electromotive force decreases until it is no longer present as the lines of force oppose it and the inductor field builds up

X. Self-inductance

A. Electromotive force should decrease rapidly once the inductive field around the inductor is at a minimum and the current reverses polarity

B. Field tries to continue in the same direction or opposes flow of current due to the direction of the field of the inductor

C. Inductor's effect of trying to continue in the same direction is then called a *counter-counter electromotive force* (CCemf), or *self-inductance*

XI. Mutual inductance

A. Applying current to a coil will create a magnetic field around the coil

B. By placing another coil near the coil with the induced current, the magnetic field will cut across the second coil causing current flow

XII. Methods of increasing the coefficient of coupling (Transparency #4)

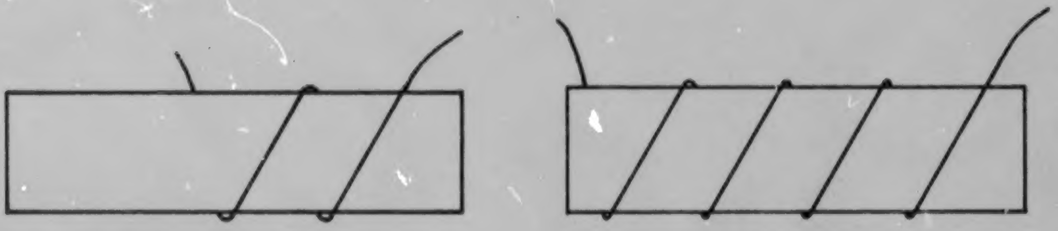
(NOTE: Coefficient of coupling is 100% if all lines of flux link both coils. This 100% is stated as having a *coefficient* or *K* of 1.)

A. Place coils closer together

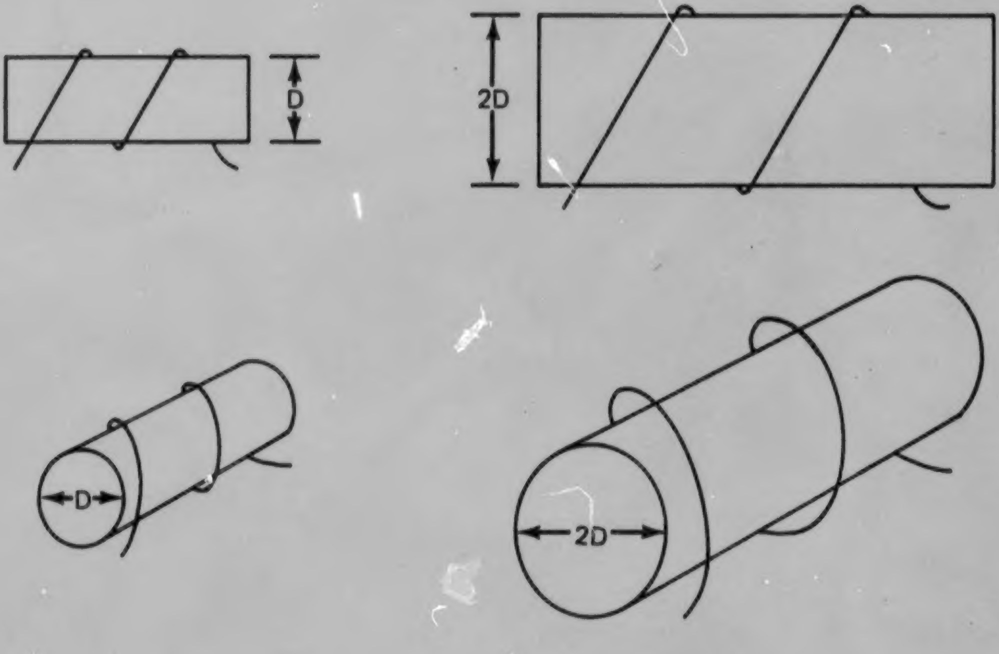
B. Place coils parallel, rather than perpendicular

C. Wind coils on a common core

Factors That Determine Inductance



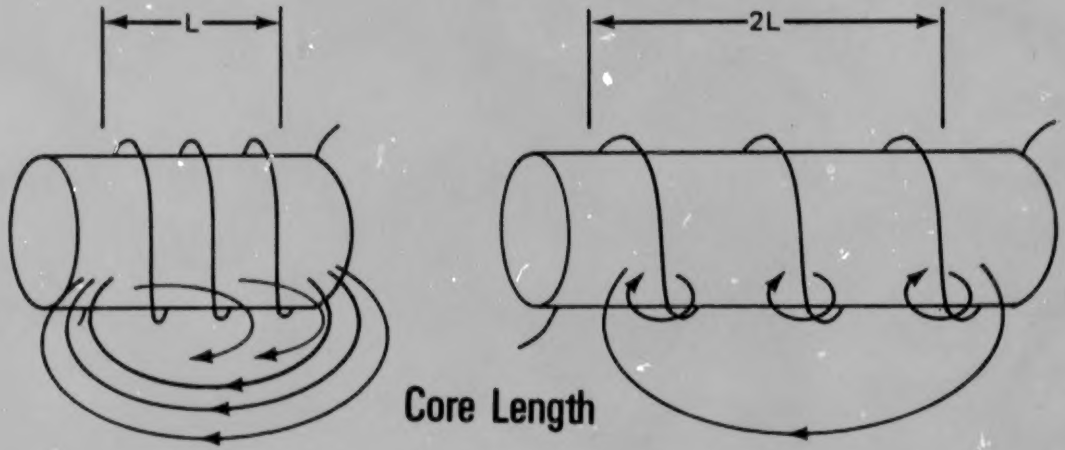
Number of Turns of Coil



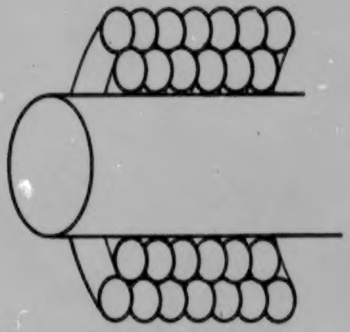
Core Diameter

Factors That Determine Inductance

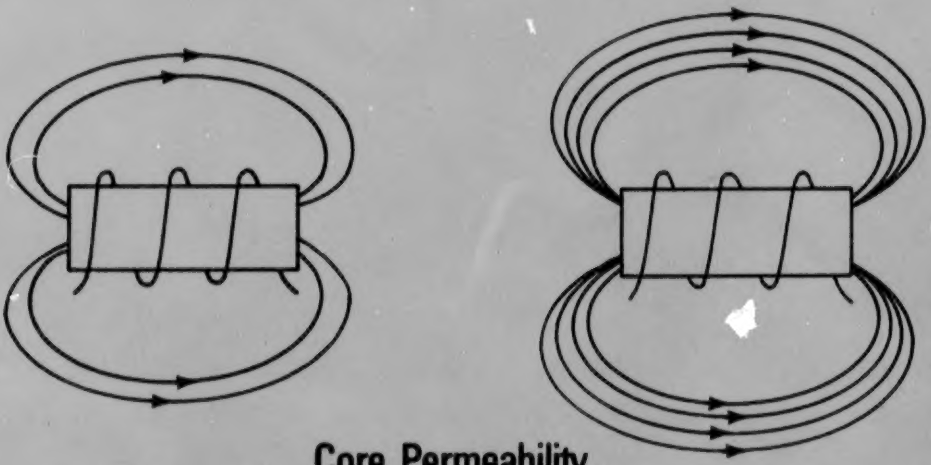
(Continued)



Core Length

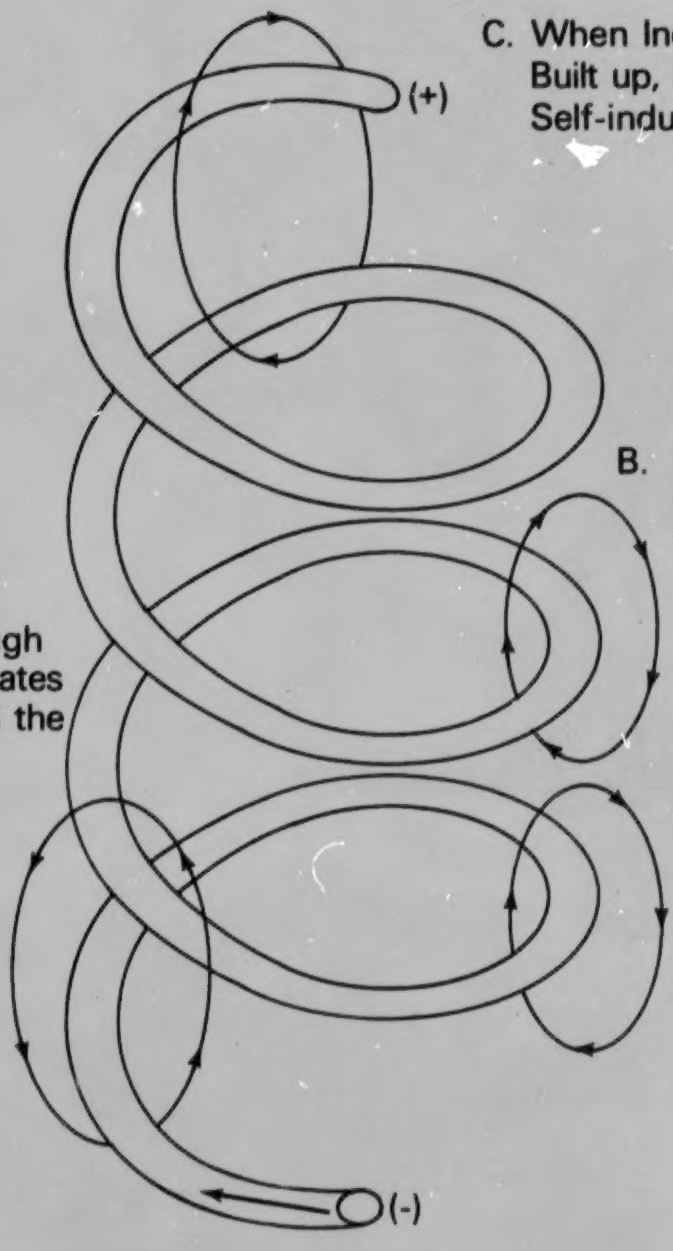


Number of Core Coil Layers



Core Permeability

Inductor Build-up

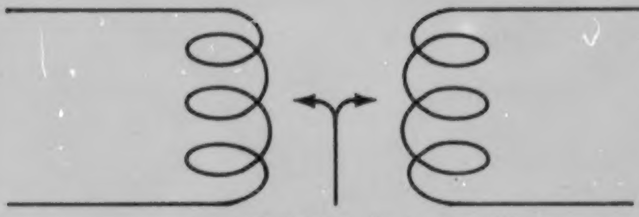


C. When Inductor Field is Built up, a Ccemf or Self-inductance Exists

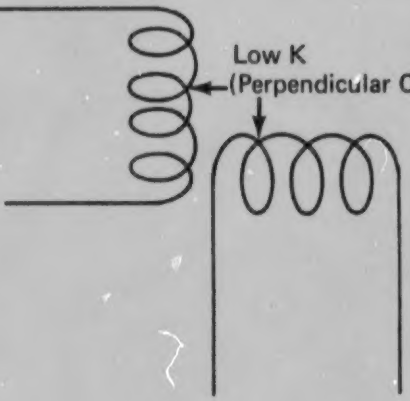
B. Flux Lines Oppose, Causing Cemf

A. Current Through Conductor Creates a Flux Around the Conductor

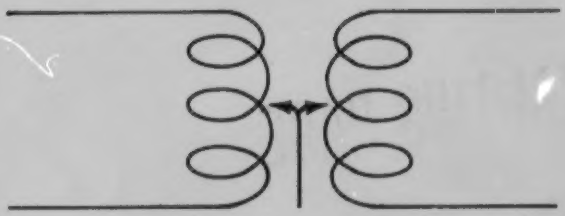
Coefficient of Coupling



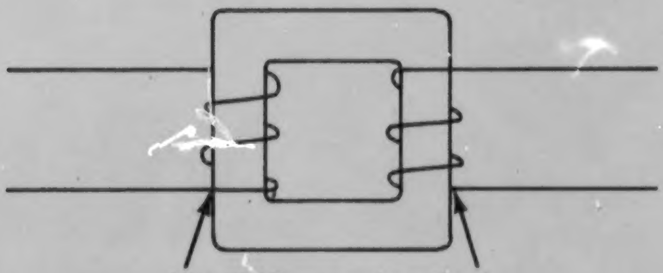
Low K (Widely Spaced Coils)



Low K (Perpendicular Coils)



High K (Close Parallel Coils)



High K (Common Iron Core)

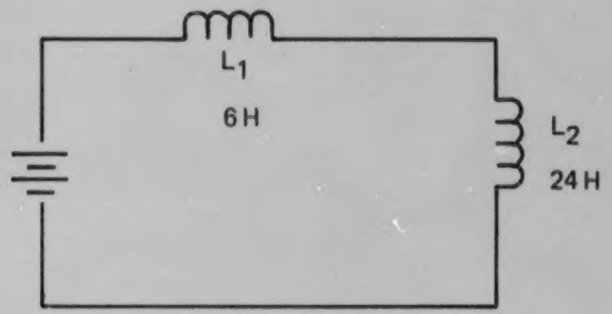
INDUCTORS
UNIT III

ASSIGNMENT SHEET #1--CALCULATE TOTAL INDUCTANCE IN A SERIES CIRCUIT

NAME ________________________ SCORE ____________

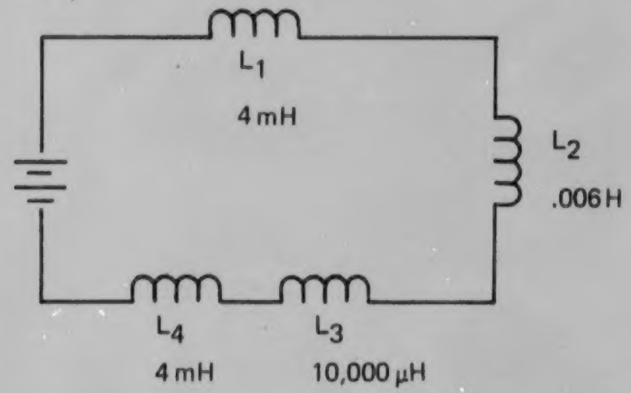
Calculate total inductance in series circuits. Write your answers in the blanks below each circuit. (Figures 8-10)

FIGURE 8



A. L_t = ______________________________

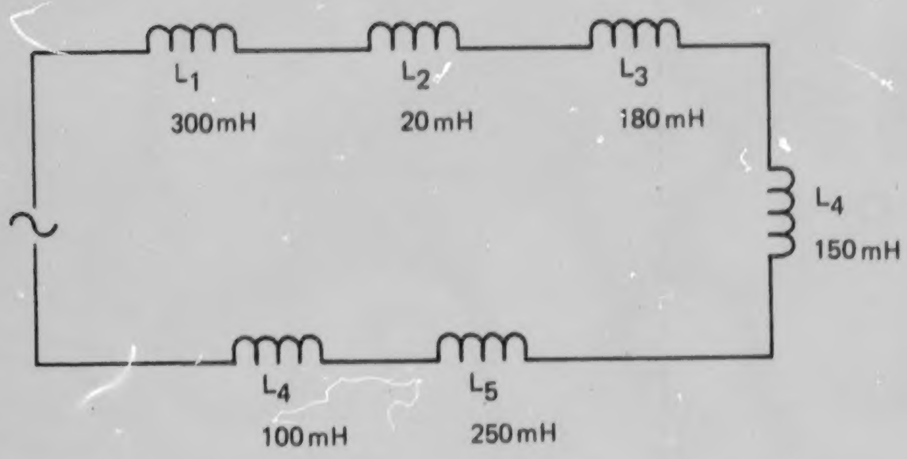
FIGURE 9


L_1
4 mH
L_2
.006 H
L_4
4 mH
L_3
10,000 μH

B. L_t = ______________________________

ASSIGNMENT SHEET #1

FIGURE 10


L_1
300 mH
L_2
20 mH
L_3
180 mH
L_4
150 mH
L_4
100 mH
L_5
250 mH

C. L_t = ______________________________

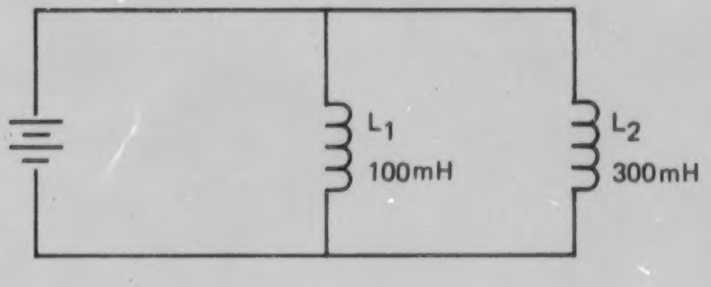
INDUCTORS
UNIT III

ASSIGNMENT SHEET #2--CALCULATE TOTAL INDUCTANCE IN A PARALLEL CIRCUIT

NAME ______________________ SCORE ______________

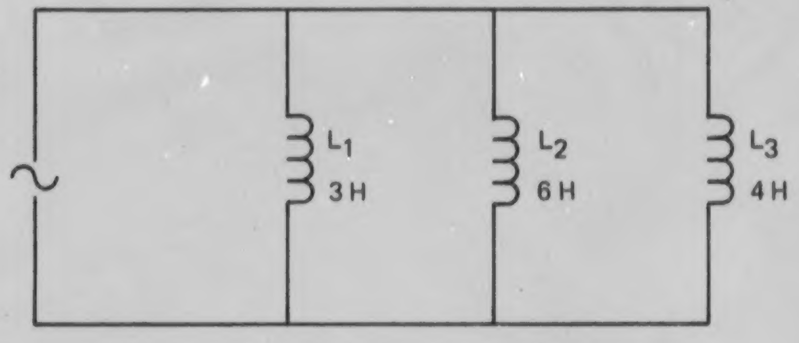
Calculate total inductance in parallel circuits. Write your answers in the blanks below each circuit. (Figures 11-13)

FIGURE 11


L_1
100mH
L_2
300mH

A. L_t = ______________________

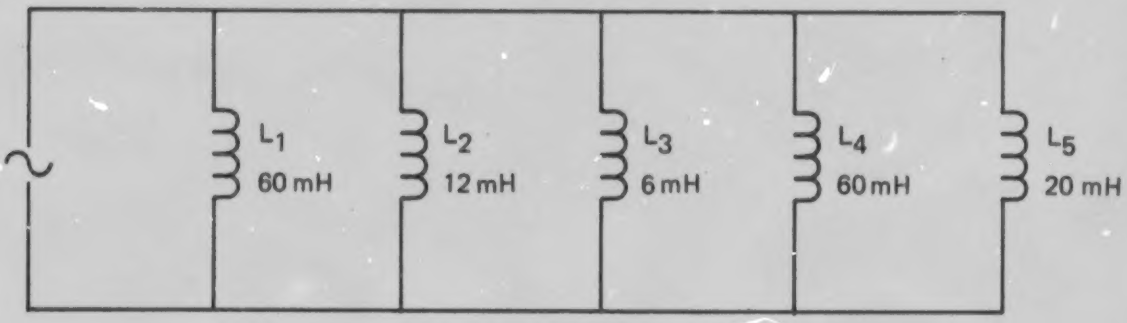
FIGURE 12


L_1
3 H
L_2
6 H
L_3
4 H

B. L_t = ______________________

ASSIGNMENT SHEET #2

FIGURE 13


L1
60 mH
L2
12 mH
L3
6 mH
L4
60 mH
L5
20 mH

C. L_t = ____

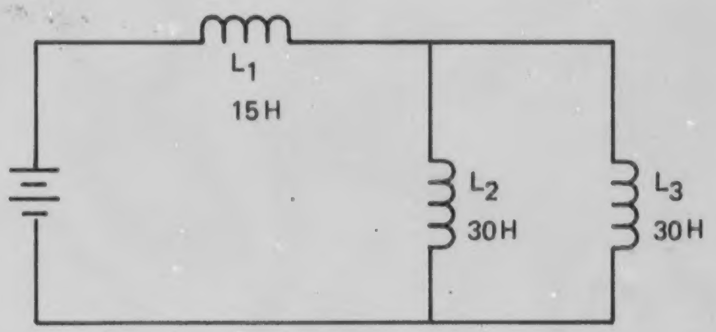
INDUCTORS
UNIT III

ASSIGNMENT SHEET #3--CALCULATE TOTAL INDUCTANCE IN A SERIES-PARALLEL CIRCUIT

NAME ______________________ SCORE ______________

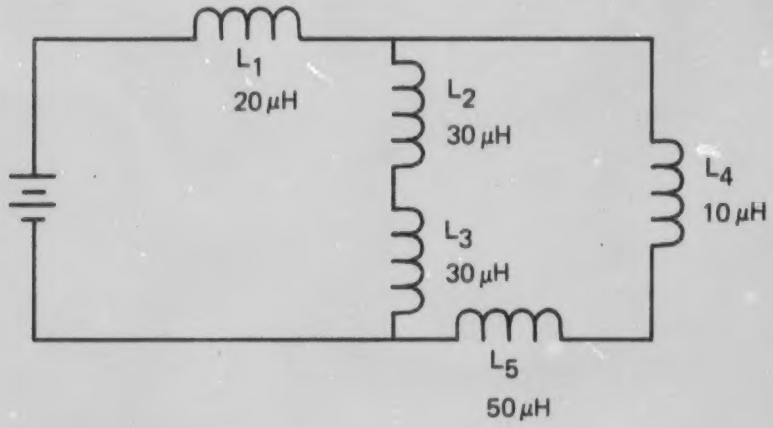
Calculate total inductance in series-parallel circuits. Write your answers in the blanks below each circuit. (Figures 14-16)

FIGURE 14


L_1
15 H
L_2
30 H
L_3
30 H

A. L_t = ______________________________

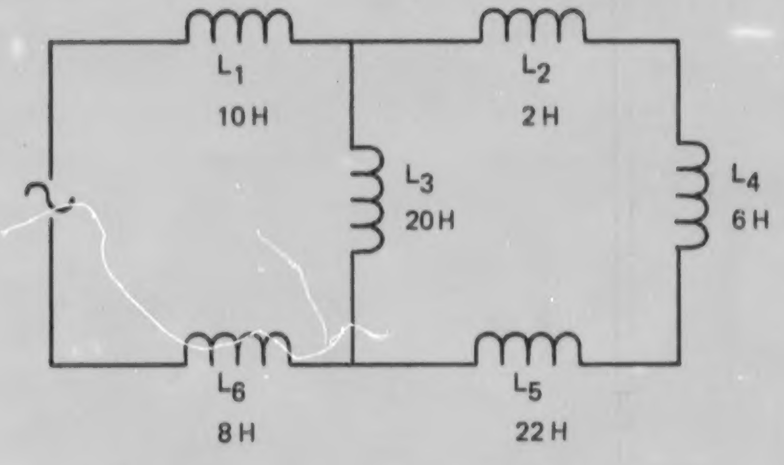
FIGURE 15


L_1
20 µH
L_2
30 µH
L_3
30 µH
L_4
10 µH
L_5
50 µH

B. L_t = ______________________________

ASSIGNMENT SHEET #3

FIGURE 16


L_1
10 H
L_2
2 H
L_3
20 H
L_4
6 H
L_6
8 H
L_5
22 H

C. L_t = ______________________

INDUCTORS
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 30 H

B. 24 mH

C. 1 H

Assignment Sheet #2

A. 75 mH

B. 1.3 H

C. 3 mH

Assignment Sheet #3

A. 20 H

B. 50 μH

C. 30 H

INDUCTORS
UNIT III

JOB SHEET #1--OPERATE AN INDUCTANCE METER

I. Equipment and materials

A. Inductance meter

B. Inductors--Type determined by your instructor

C. Instruction booklet

II. Procedure

A. Use the instruction booklet to review the operating instructions for the inductance tester

B. Follow the operating instructions for use of the inductance tester

C. Measure the inductance of the inductor

D. Record the value below

L = ______________________________

E. Make a ringing test on the inductor

F. Does the inductor meet specifications? ____________________

G. Repeat steps C through F for each inductor being tested

H. Record values below

Inductance ______________ Ringing Test ______________

Inductance ______________ Ringing Test ______________

Inductance ______________ Ringing Test ______________

I. Compare the inductance reading with the values of the inductors

(NOTE: Show your results to the instructor.)

J. Put equipment and materials away

INDUCTORS
UNIT III

TEST

NAME ______________________________ SCORE ____________________

1. Match terms associated with inductors to their correct definitions. Write the correct numbers in the blanks.

_____a. Component of an electrical circuit that produces inductance

_____b. The percentage of flux between linking coils; expressed as a decimal

_____c. Number of turns of wire that is wound around an iron core or form of insulating material

_____d. Physical property of an inductor that opposes any change in current flow

_____e. Conductor's ability to induce voltage in itself when current changes

_____f. Production of an electric charge or magnetic field in a substance by an electrical source, magnet, or magnetic field

_____g. Linking lines of force from one current-carrying conductor to another

_____h. Unit of measurement for inductance or mutual inductance

_____i. Force or voltage that causes current flow through an inductor

_____j. Inductance used to impede AC flow

_____k. Voltage developed in an inductor which is opposite that of the applied voltage at every instant

_____l. Any magnetic lines that do not link two coils

1. Inductance
2. Electromotive force
3. Counter electromotive force
4. Self-inductance
5. Coefficient of coupling
6. Leakage flux
7. Choke
8. Inductor
9. Coil
10. Henry
11. Induction
12. Mutual inductance

TEST

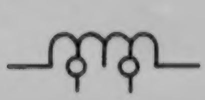
2. Match abbreviations associated with inductors to their correct definitions. Write the correct numbers in the blanks.

_____a. Henry
_____b. Microhenry
_____c. Total inductance
_____d. Millihenry
_____e. Counter electromotive force
_____f. Direct current
_____g. Inductance, inductor
_____h. Electromotive force
_____i. Coefficient of coupling
_____j. Equivalent inductance
_____k. Mutual inductance
_____l. Alternating current
_____m. Permeability

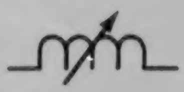
1. DC
2. emf
3. H
4. AC
5. L_e
6. Camf
7. L
8. L_t
9. K
10. L_m
11. μ
12. mH
13. μH

3. Identify schematic symbols associated with inductors. Write the correct answers from the list below in the blanks under each symbol.

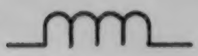
Air core inductor
Iron core inductor
Tapped inductor
Variable inductor



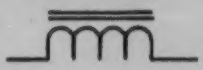
a. ______________________



b. ______________________



c. ______________________



d. ______________________

TEST

4. List basic-core types of inductors.

a. ______________________

b. ______________________

5. List factors that determine inductance.

a. ______________________

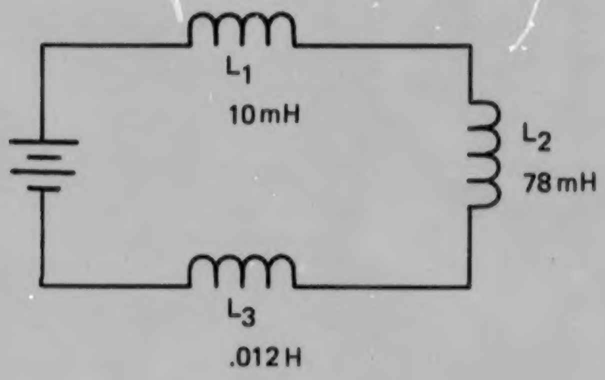
b. ______________________

c. ______________________

d. ______________________

e. ______________________

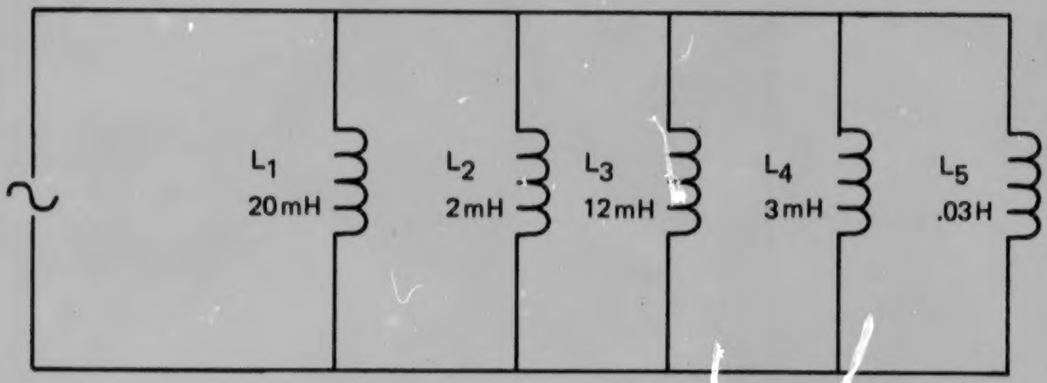
6. Calculate total inductance in a series circuit.


L_1
10 mH
L_2
78 mH
L_3
.012 H

L_t = ______________________

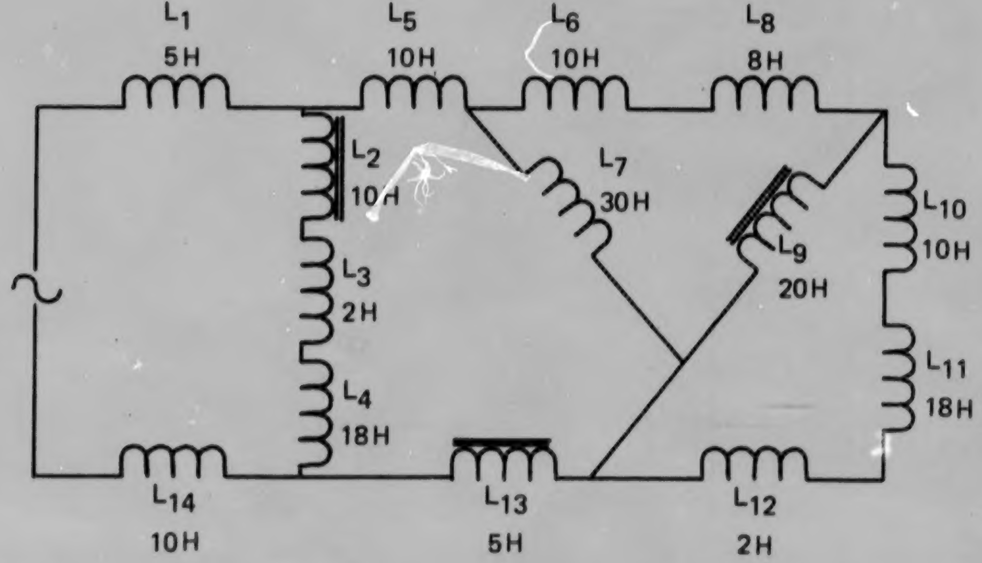
TEST

7. Calculate total inductance in a parallel circuit.


L1
20mH
L2
2mH
L3
12mH
L4
3mH
L5
.03H

L_t = ____________________

8. Calculate total inductance in a series-parallel circuit.


L1
5H
L5
10H
L6
10H
L8
8H
L2
10H
L7
30H
L10
10H
L9
20H
L3
2H
L4
18H
L11
18H
L14
10H
L13
5H
L12
2H

L_t = ____________________

TEST

9. Discuss Lenz's Law as it applies to inductors.

10. Explain self-inductance.

TEST

11. Explain mutual inductance.

12. State methods of increasing the coefficient of coupling.

a.

b.

c.

(NOTE: Test question 13 is a job sheet. It is an important part of this unit. If it has not been completed, check with your instructor.)

13. Demonstrate the ability to operate an inductance meter.

INDUCTORS
UNIT III

ANSWERS TO TEST

1. a. 8
   b. 5
   c. 9
   d. 1
   e. 4
   f. 11
   g. 12
   h. 10
   i. 2
   j. 7
   k. 3
   l. 6

2. a. 3
   b. 13
   c. 8
   d. 12
   e. 6
   f. 1
   g. 7
   h. 2
   i. 9
   j. 5
   k. 10
   l. 4
   m. 11

3. a. Tapped inductor
   b. Variable inductor
   c. Air core inductor
   d. Iron core inductor

4. a. Air
   b. Iron

5. a. Number of turns of coil
   b. Core diameter
   c. Core length
   d. Core permeability
   e. Number of coil layers

6. 100 mH

ANSWERS TO TEST

7. 1 mH

8. 30 H

9. Answer should include

   a. Induced voltage builds a field around the conductor

   b. Shape of the inductor causes the field of one coil to be in opposition to the field of an adjacent coil, thus causing an opposition to current flow

   c. Counter electromotive force causes current to begin building slowly

   d. Counter electromotive force decreases until it is no longer present as the lines of force oppose it and the inductor field builds up

10. Answer should include

    a. Electromotive force should decrease rapidly once inductive field around the inductor is at a maximum and the current reverses polarity

    b. Field tries to continue in the same direction or opposes flow of current due to the direction of the field around the inductor

    c. The inductor's effect of trying to continue in the same direction is then called *counter-counter electromotive force* (CCemf), or *self-inductance*

11. Answer should include

    a. Applying current to a coil will create a magnetic field around the coil

    b. By placing another coil near the coil with the induced current, the magnetic field will cut across the second coil causing current flow

12. a. Place coils closer together

    b. Place coils parallel, rather than perpendicular

    c. Wind coils on a common core

13. Performance skills evaluated to satisfaction of instructor

TRANSFORMERS
UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to identify color codes of transformers, identify single-phase and three-phase transformer connections, and be able to evaluate transformers for operation. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with transformers to their correct definitions.
2. Name abbreviations and symbols associated with transformers.
3. Label transformer circuit symbols.
4. Match types of transformers to their correct descriptions and applications.
5. List types of transformer power losses.
6. Discuss methods of reducing power loss in transformers.
7. Identify types of single-phase transformer connections.
8. Identify types of three-phase transformer connections with delta-connected primaries.
9. Identify types of three-phase transformer connections with wye-connected primaries.
10. List methods of identifying transformer leads for hook-up.
11. Calculate transformer values.
12. Arrange in order the steps in identifying three-phase transformer connections.
13. Calculate the power in three-phase circuits.
14. Calculate transformer power, voltage, and current.
15. Find faults in transformer wiring diagrams.
16. Diagram transformer connections for three-phase power.

OBJECTIVE SHEET

17. Demonstrate the ability to
    a. Check transformer polarities with a voltmeter.
    b. Examine the frequency response of a transformer.
    c. Set up transformer backfeed in a parallel circuit.
    d. Determine the configuration of a multiple-winding transformer.
    e. Check a transformer using an insulation tester.

TRANSFORMERS
UNIT IV

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Set up an oscilloscope demonstration of three-phase timing using a dual-trace scope.

   H. Show the many types of transformers and how many specifications a transformer may have.

   I. Using an oscilloscope, demonstrate transformer frequency response.

   J. Demonstrate the proper and safe method of using an insulation tester to test a transformer.

   K. Make a transformer for demonstration.

      1. Wind bell wire (above AWG #20 gauge) around an iron bolt, making two side-by-side coils.

      2. Apply a low alternating current to one coil and measure the other.

      3. Count the wraps and demonstrate the ratio of wraps to the voltage.

   L. Discuss sections of the *National Electrical Code*, dealing with transformer circuits.

   M. Give test.

II. Instructional materials

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM #1--Types of Transformers

      2. TM #2--Voltage Waveforms

SUGGESTED ACTIVITIES

3. TM #3--Procedure For Identifying Three-Phase Connections
4. TM #4--Procedure for Identifying Three-Phase Connections (Continued)
5. TM #5--Three-Phase Voltage, Current, and Power

D. Assignment sheets

1. Assignment Sheet #1--Calculate Transformer Power, Voltage, and Current
2. Assignment Sheet #2--Find Faults in Transformer Wiring Diagrams
3. Assignment Sheet #3--Diagram Transformer Connections for Three-Phase Power
4. Assignment Sheet #4--Identify Types of Transformer Connections
5. Assignment Sheet #5--Calculate Power in Three-Phase Circuits

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1--Check Transformer Polarities With a Voltmeter
2. Job Sheet #2--Examine The Frequency Response of a Transformer
3. Job Sheet #3--Set Up Transformer Backfeed in a Parallel Circuit
4. Job Sheet #4--Determine The Configuration of a Multiple-Winding Transformer
5. Job Sheet #5--Check a Transformer Using an Insulation Tester

G. Test

H. Answers to test

III. Unit references

A. Alerich, Walter N. *Electricity 3.* Albany, New York: Delmar Publishers, 1974.

B. Gebert, Kenneth L. and Kenneth R. Edwards. *Transformers.* 2nd ed. Chicago: American Technical Society, 1974.

C. *National Electrical Code.* Boston: National Fire Protection Association, 1980.

D. *Transformers and AC Circuits, Unit 3.* Barrington, Illinois: TPC Training Systems, Division of Technical Publishing Co., 1975.

TRANSFORMERS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. One-line diagram--Schematic diagram where one line represents other lines as well; usually represents three-phase power in power distribution systems and high voltage substations

B. Hysteresis loss--Power lost in magnetizing metal from one direction to another

C. Eddy currents–Small electrical currents that travel in circular paths within a piece of metal subjected to magnetic forces

D. Neutral conductor--Power distribution cable at a ground potential, but may conduct current to complete circuit

(NOTE: A neutral conductor is not a "safety ground." A safety ground doesn't normally carry any current except during short-circuits.)

E. Single-phase power--Alternating current power consisting of a single voltage waveform (Transparency #2)

EXAMPLE: Power available from an ordinary wall receptacle

F. Two-phase power--Alternating current power consisting of two voltage waveforms that peak 90° apart (Transparency #2)

(NOTE: Two-phase power is not common, but it is used by some industries. The 90° phase relationship differentiates two-phase from merely two phases of three-phase.)

G. Three-phase power--Alternating current power consisting of three voltage waveforms that peak 120° apart (Transparency #2)

H. Polyphase–More than one phase

EXAMPLES: Two-phase, three-phase, six-phase

I. Turns ratio–Ratio of the number of turns in the primary winding to the number of turns in the secondary winding of a transformer

EXAMPLE: 100 turns primary to 200 turns secondary would be a ratio of 1:2

II. Abbreviations and symbols associated with transformers

A. XFMR--Transformer

B. kVA--Kilovolt amperes

C. emf--Electromagnetic force

INFORMATION SHEET

D. HV--High voltage

(NOTE: HVAC should not be interpreted as "high voltage AC" because it is used primarily to mean "heating, ventilation, and air conditioning.")

E. Pri--Primary

F. Sec--Secondary

G. CT--Center tap

H. PT--Potential transformer

I. I^2R--Current squared times resistance

(NOTE: I^2R represents the power lost as heat in any circuit.)

J. P--Power

K. I--Current

L. E--Voltage

M. kW--Kilowatt

N. W--Watt

O. N_p--Number of primary coil wraps

P. N_s--Number of secondary coil wraps

Q. ϕ--Phase

R. VAC--Volts alternating current

S. VDC--Volts direct current

T. V--Volt

U. A--Ampere

V. VA--Volt amperes

W. E_p--Voltage in primary

X. E_s--Voltage in secondary

Y. I_p--Current in primary

Z. I_s--Current in secondary

AA. Δ--Greek leter *delta*; indicates a circuit configuration

BB. Y --Wye, or star; indicates a circuit configuration

INFORMATION SHEET

CC. ⏚ --Symbol for ground connection

DD. ╋ --Symbol for wire connections

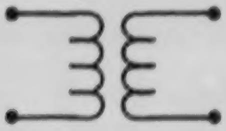
EE. ┼ --Symbol for wires not connected

III. Transformer circuit symbols (Figures 1-11)

(NOTE: The iron core of a power transformer usually is assumed and not always indicated in the symbol. Similarily, the grounded status of the core is not always indicated except for emphasis.)

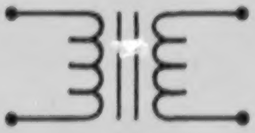
A. Simple air-core transformer

FIGURE 1



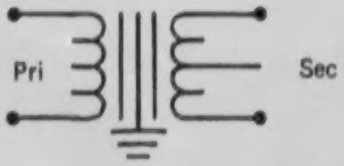
B. Simple iron-core transformer

FIGURE 2



C. Iron-core transformer with grounded core and center tap secondary

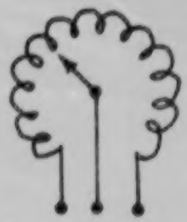
FIGURE 3



INFORMATION SHEET

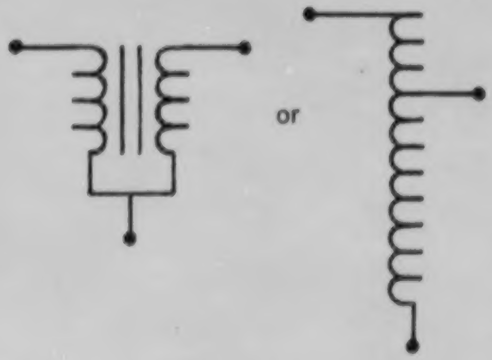
D. Variable auto transformer

FIGURE 4



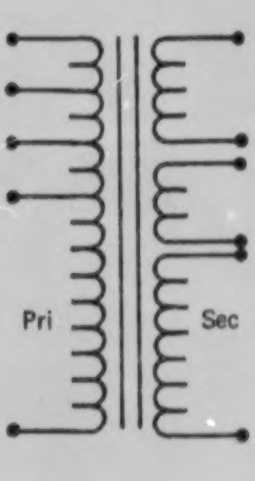
E. Autotransformer

FIGURE 5



F. Multitap primary; multiple secondary transformer

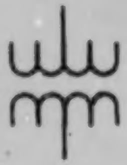
FIGURE 6



INFORMATION SHEET

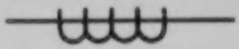
G. One-line diagram transformer

FIGURE 7



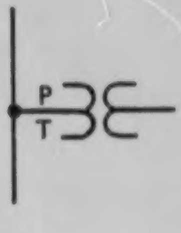
H. One-line diagram current transformer

FIGURE 8



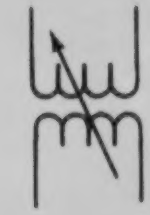
I. One-line diagram potential transformer

FIGURE 9



J. Variable core transformer

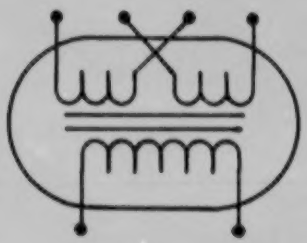
FIGURE 10



INFORMATION SHEET

K. Standard power distribution transformer

FIGURE 11



IV. Transformer descriptions and applications (Transparency #1)

A. Potential transformer--Step-down transformer used to measure high voltage by stepping voltage down by a known fraction to a measurable value

B. Current transformer--Step-down transformer used to measure high current and provide isolation from high voltages; provides a fraction of current to gauge value of total current

C. Air-core transformer–Transformer without an iron or metal core; usually applied to low power, high frequency applications

D. Autotransformer–Transformer whose primary and secondary windings are of a common core and share a common connection

E. Iron-core transformer--Transformer having metal core usually made of laminations of iron or steel; usually applied to low frequency, high power applications

F. Toroidal transformer--Transformer having a ring-shaped core around which windings are wrapped

G. Isolation transformer–Transformer used to isolate circuits from a common ground, from direct current potentials, or to improve power transfer by impedance matching improvement, often providing no change in voltage

H. Variac--Variable autotransformer that can be varied while operating

I. Step-down transformer--Transformer used to reduce voltage while often increasing current capability above that of the source

INFORMATION SHEET

J. Step-up transformer–Transformer used to increase voltage, often while sacrificing current capability of source

(NOTE: Because of the laws of energy conservation, step-up and step-down transformers always sacrifice current for voltage or vise versa as measured from the primary to the secondary.)

K. Spark coil--High voltage transformer, usually an autotransformer; often used to develop high voltage ignition for gasoline engines and gas firing devices

L. Booster transformer–Additional transformer placed in a transmission or distribution line to boost voltage to an acceptable level from a reduced level caused by line length

V. Types of transformer power losses

A. Conductor loss

B. Core loss

C. Insulation loss

VI. Methods of reducing power loss in transformers

A. Conductor loss--Reduced by using good conductors

(NOTE: Conductor loss may also be referred to as *heat loss* or *I^2 loss.*)

EXAMPLES: Use of copper in manufacturing; not overloading with excessive current

B. Core loss

1. Hysteresis loss--Reduced by making core out of material suitable for operating frequency

2. Eddy current loss–Reduced by making core in form of laminations or sheets of metal which are insulated from each other

3. Flux loss--Reduced through core construction design and shielding

C. Insulation loss–Reduced with good insulation material, including oil or other coolant material

(NOTE: Insulation loss also may be referred to as *leakage current*.)

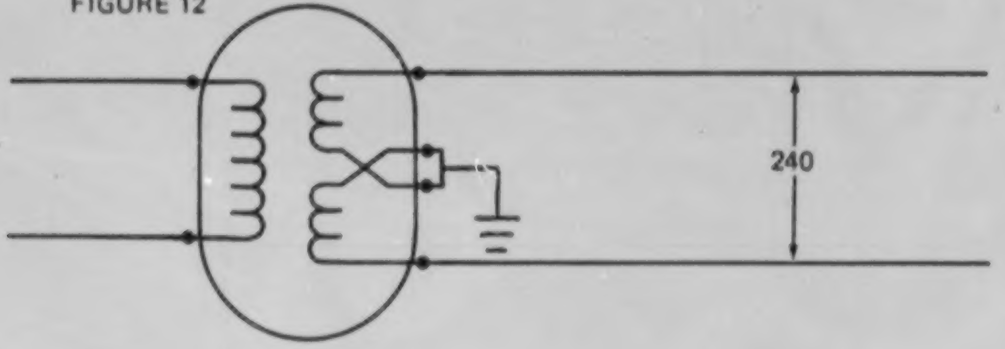
VII. Types of single-phase tra[illegible]rmer connections (Figures 12-17)
17)

(NOTE: Transformers shown are standard power distribution types with two 120-volt secondary windings. A single winding or two in parallel will produce 120 volts. Both windings in series will produce 240 volts. Grounded terminals produce the "neutral conductor.")

INFORMATION SHEET

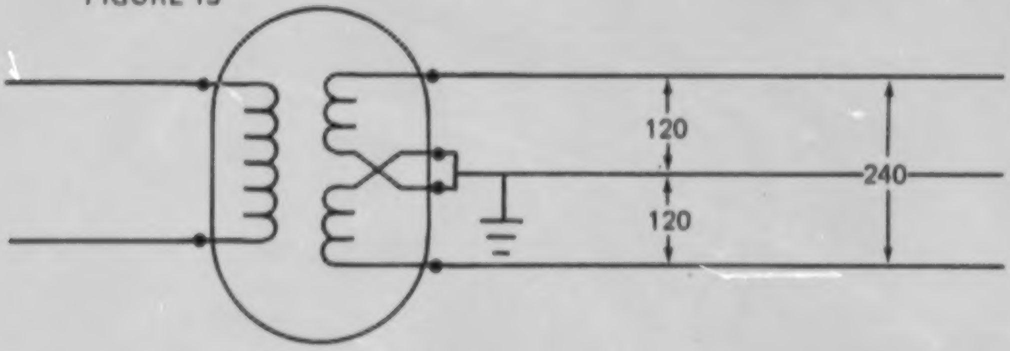
A. 240 volts, two-wire

FIGURE 12



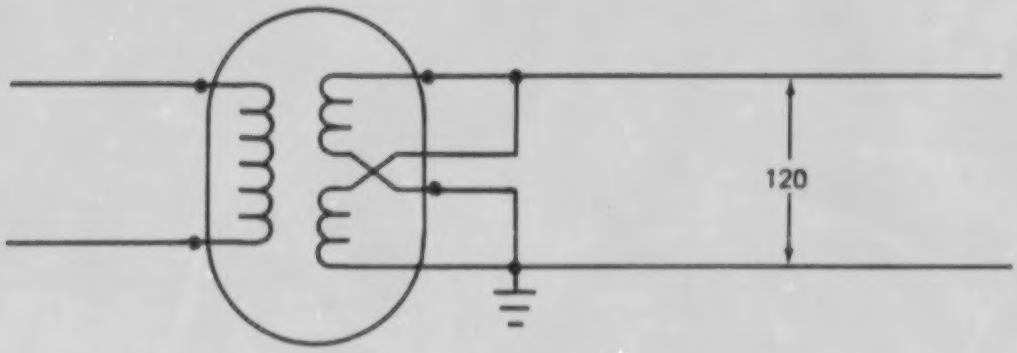
B. 120/240 volts, three-wire

FIGURE 13



C. 120 volts, two-wire

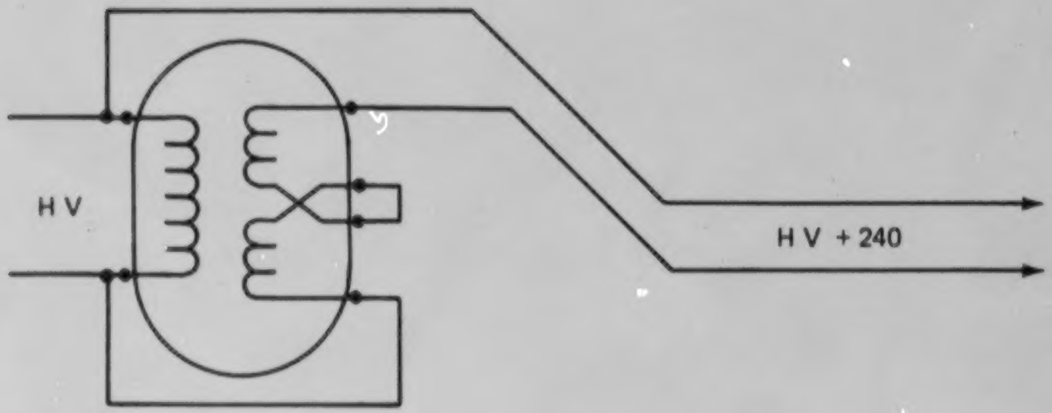
FIGURE 14



INFORMATION SHEET

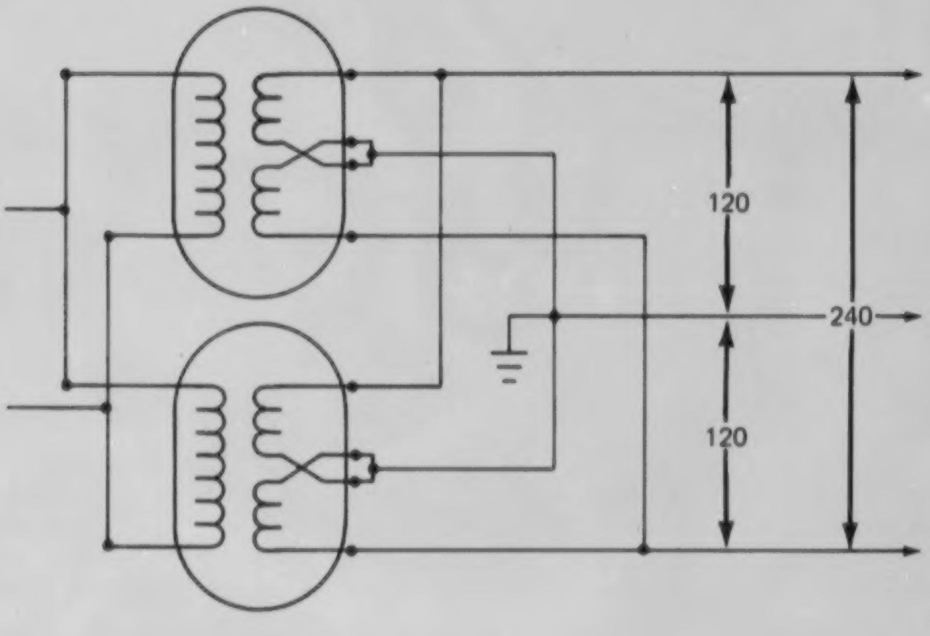
D. High voltage, boosted by 240 volts

FIGURE 15



E. 120/240 volts, three-wire with additional power capacity of two transformers

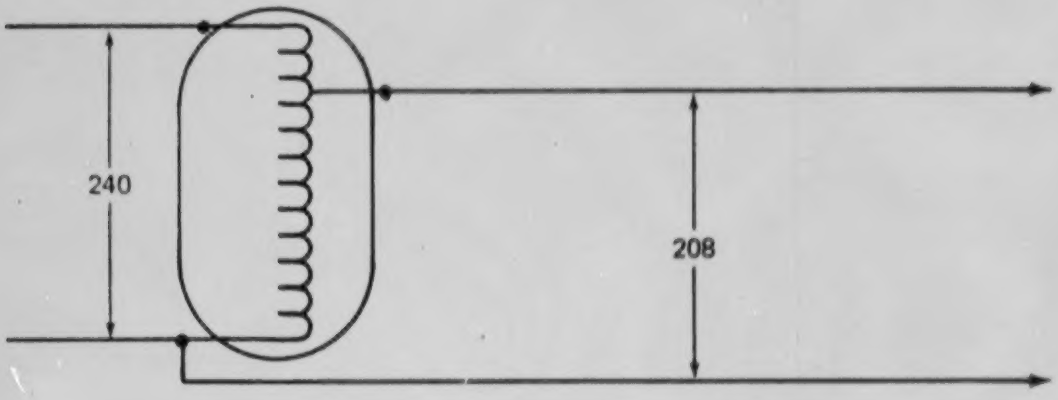
FIGURE 16



INFORMATION SHEET

F. 208 volts, two-wire from 240 volt through autotransformer

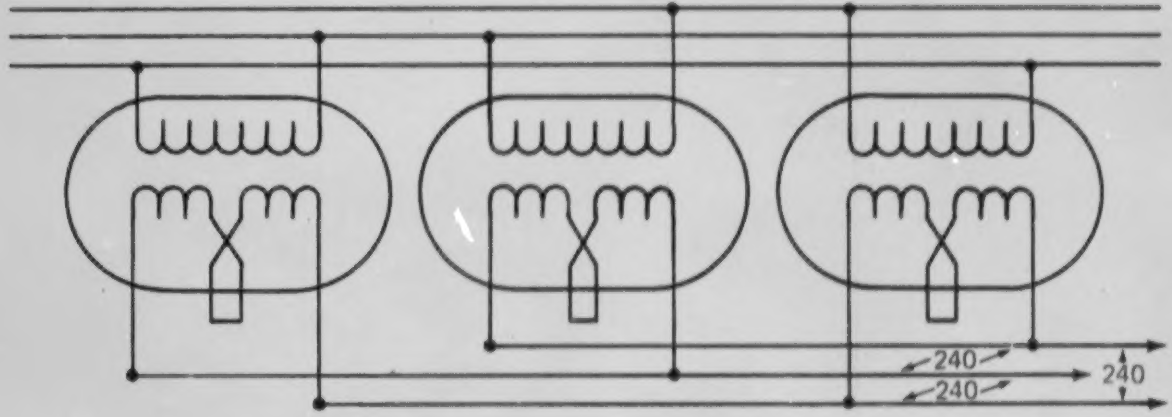
FIGURE 17



VIII. Types of three-phase transformer connections with delta-connected primaries (Assignment Sheets #3 and #4; Figures 18-23)

A. Three-wire, 240 volts, delta-delta

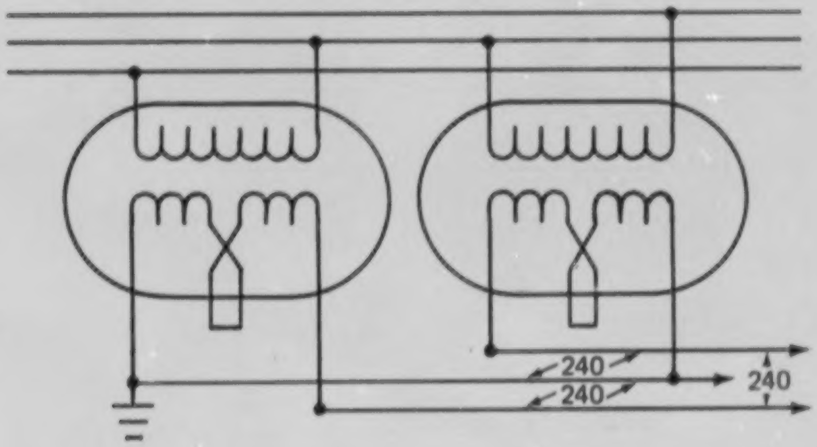
FIGURE 18



INFORMATION SHEET

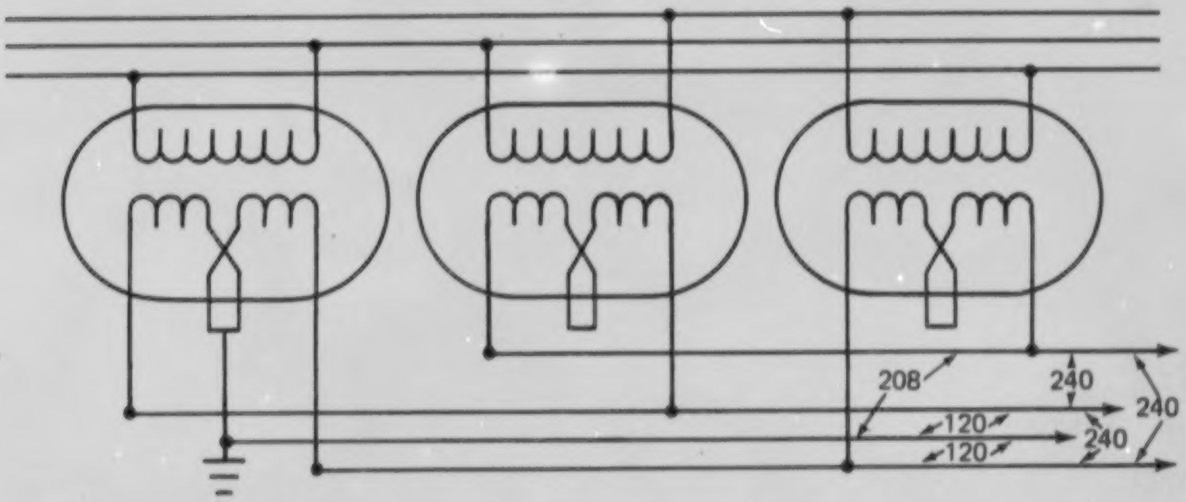
B. Three-wire, 240 volts, open delta

FIGURE 19



C. Four-wire, 120/240 volts, delta-delta

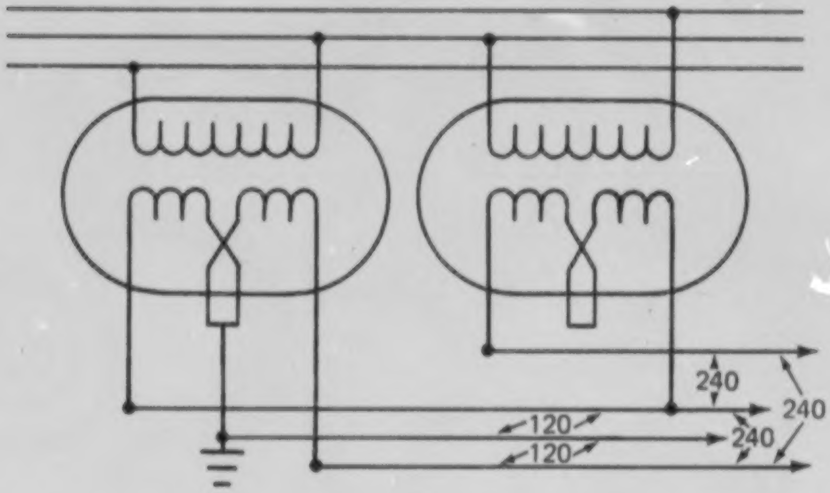
FIGURE 20


208
240
240
120
240
120

INFORMATION SHEET

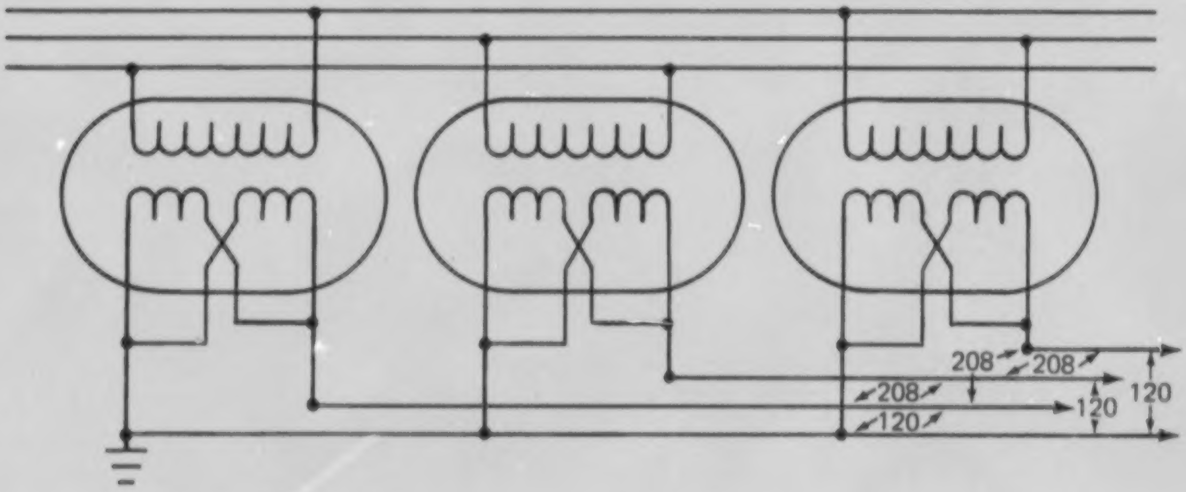
D. Four-wire, 120/240 volts, open delta

FIGURE 21


240
240
120
240
120

E. Four-wire, 120/208 volts, delta-wye

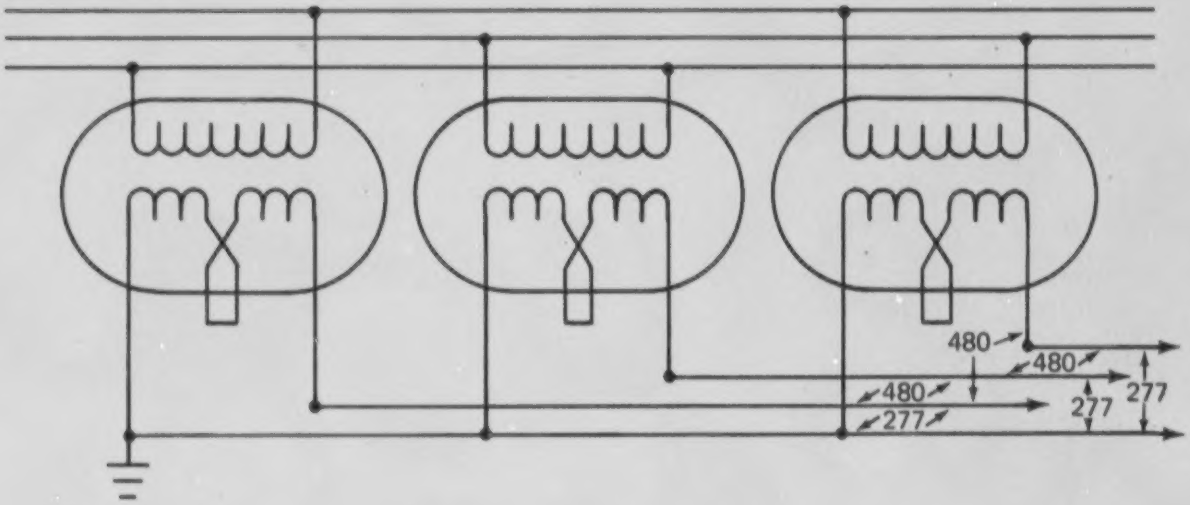
FIGURE 22


208
208
208
120
120
120

INFORMATION SHEET

F. Four-wire, 277/480 volts, delta-wye

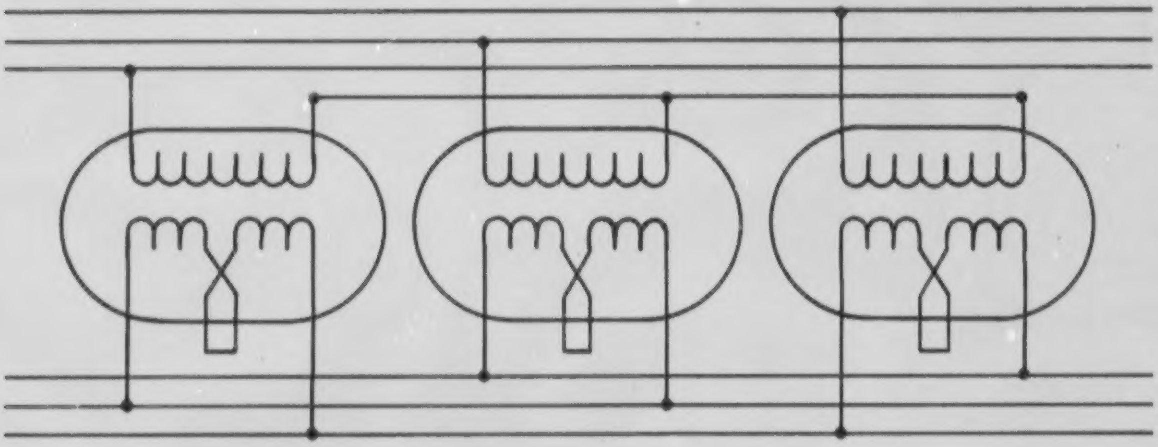
FIGURE 23



IX. Types of three-phase transformer connections with wye-connected primaries (Assignment Sheet #4; Figures 24-28)

A. Three-wire, 240 volts, wye-delta

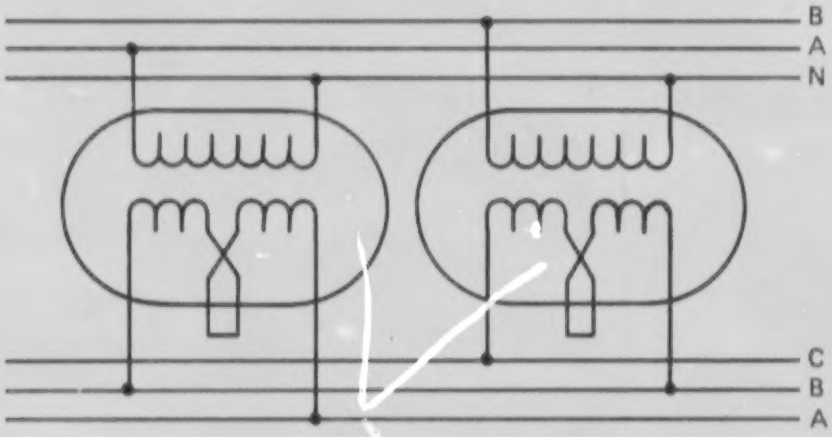
FIGURE 24



INFORMATION SHEET

B. Three-wire, 240 volts, open wye to open delta

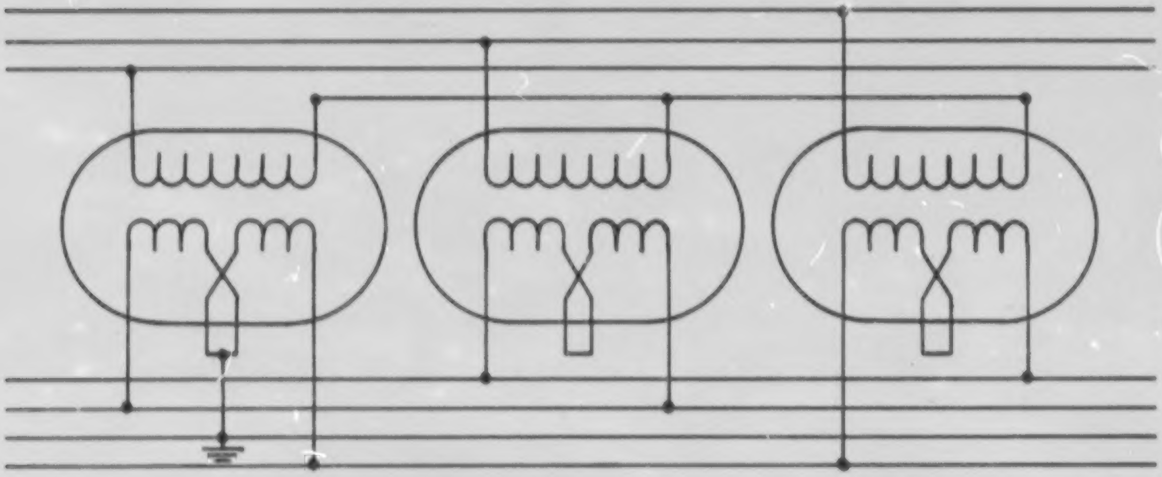
FIGURE 25



(NOTE: The letter designations indicate power phase hook-up requirements.)

C. Four-wire, 120/240 volts, wye-delta

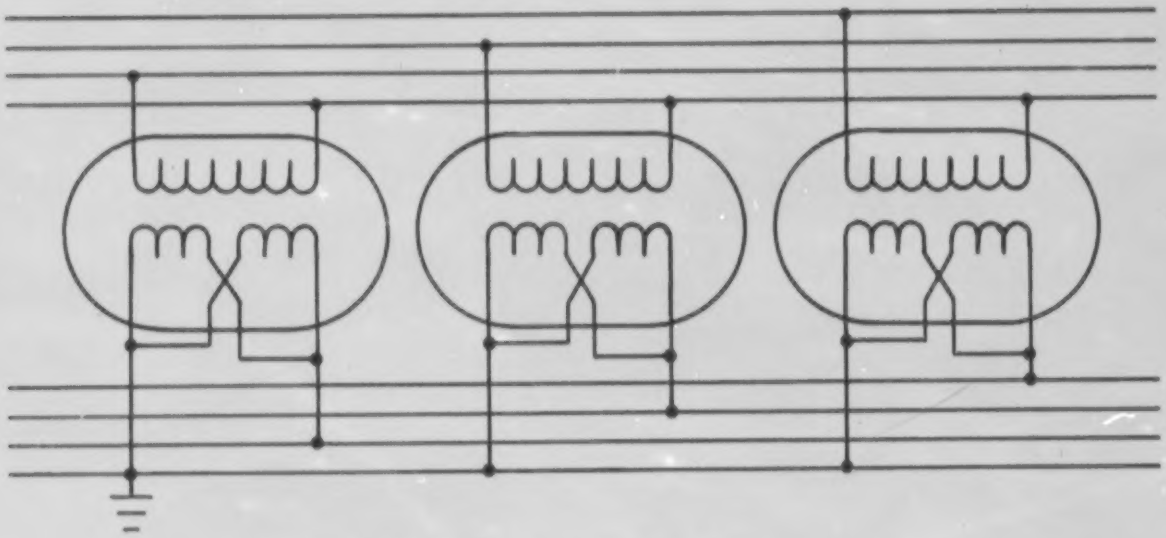
FIGURE 26



INFORMATION SHEET

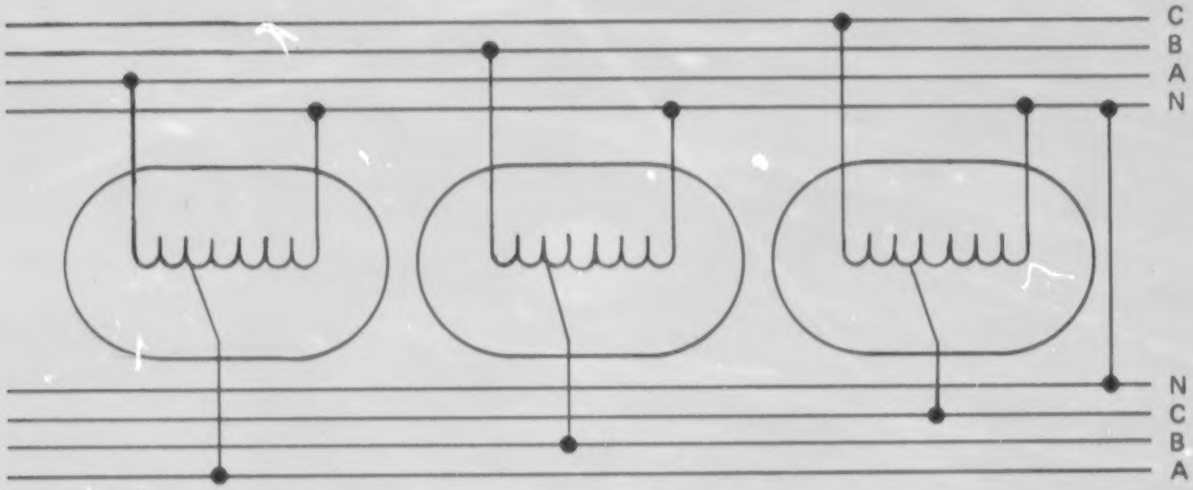
D. Four-wire, 120/208 volts, wye-wye

FIGURE 27



E. Four-wire, 240 to 208 volts, autotransformer, wye-wye

FIGURE 28



(NOTE: The letter designations indicate power phase hook-up requirements.)

INFORMATION SHEET

X. Identifying transformer leads for hook-up

(NOTE: One transformer lead may not be color-coded or indicate continuity to any other lead. This is a shield lead and should be connected to the chassis or common ground.)

A. Transformer diagram

(NOTE: The diagram accompanying the transformer, whether on paper or on the transformer itself, will indicate the specific leads.)

B. Transformer color codes

(NOTE: Standard transformer color codes found in most electronic data books and many electronic text books will indicate specific leads.)

C. Resistance checks

(NOTE: Primary windings will have a resistance of 5 to 20 ohms; low voltage secondary windings will have a resistance of approximately 1 ohm; and high voltage secondary windings will have a resistance of 200 to 400 ohms.)

D. Voltage checks

(NOTE: Connect primary windings to power source, and measure output of secondary winding.)

XI. Calculating transformer values (Assignment Sheet #1)

A. Power

1. At 100 percent efficiency--Use the formula

$$I_s \times E_s = I_p \times E_p$$

OR

$$P_s = P_p$$

EXAMPLE: A transformer has 15 amperes of input current and is connected across 480 volts. If it is 100% efficient, what would the output power be?

Solution: $P_s = P_p$

$= 480\text{ V} \times 15\text{ A}$

$= 7{,}200\text{ VA}$

$= 7.2\text{ kVA}$

INFORMATION SHEET

2. At known efficiency--Use the formula $P_s = P_p \times \text{Efficiency}$

EXAMPLE: Voltage connected to the primary of a transformer is 13.6 kV and the current is 10 amperes in the primary. What is the output power if the transformer is 95% efficient?

Solution: $P_s = P_p \times \text{Efficiency}$

$= 13.6 \text{ kV} \times 10 \text{ A} \times 95\%$

$= 136 \text{ kVA} \times 95\%$

$= 129.2 \text{ kVA}$

B. Voltage--Use the formula

$$\frac{N_p}{N_s} = \frac{E_p}{E_s}$$

EXAMPLE: A step-up transformer has 100 wraps of wire in its primary and 1,350 wraps in its secondary. If the input voltage is 120 volts, what will the output voltage be?

Solution:

$$\frac{N_p}{N_s} = \frac{E_p}{E_s}$$

$$\frac{100}{1350} = \frac{120}{E_s}$$

(NOTE: For ratios such as this, cross-multiplication is often used.)

$$100 \times E_s = 1{,}350 \times 120$$

$$100\,E_s = 162{,}000$$

$$E_s = 1{,}620 \text{ V}$$

INFORMATION SHEET

C. Current--Use the formula

$$\frac{N_p}{N_s} = \frac{I_p}{I_s}$$

EXAMPLE: A step-down transformer has a primary with 1,000 wraps and a secondary with 250 wraps. If the current is 2 amperes in the input, what is the output current?

Solution:

$$\frac{N_p}{N_s} = \frac{I_p}{I_s}$$

$$\frac{1000}{250} = \frac{I_s}{2}$$

$$250\ I_s = 2{,}000$$

$$I_s = 8\ \text{A}$$

(NOTE: The terms *step-up* and *step-down* apply to voltage. Current behaves oppositely. Thus, this particular step-down transformer actually increased the current.)

D. Turns ratio--Place the primary value over the secondary value; then treat the ratio as a fraction and reduce to lowest terms

(NOTE: Do not convert to a whole number.)

EXAMPLE: A step-down transformer has a primary of 1,000 wraps and a secondary of 250 wraps. What is the turns ratio?

Solution: Turns ratio $= \frac{\text{Primary}}{\text{Secondary}}$

$$= \frac{1000}{250}$$

$$= \frac{4}{1} \text{ or } 4{:}1$$

XII. Steps for identifying three-phase transformer connections (Transparency #3)

A. Label circuit components and connection points

B. Resketch circuit so that connections along the same wire are all at one point, looping wires as necessary and avoiding crossing wires as much as possible

C. Resketch circuit, omitting any wire that does not go from one device to another

INFORMATION SHEET

D. Rearrange components in one or more sketches until the configuration is determined

(NOTE: This procedure is presented to show how the names relate to the actual configurations and to give a procedure to use until configurations become readily apparent merely upon observation.)

XIII. Power in three-phase circuits (Transparency #4; Assignment Sheet #5)

A. Delta--Voltage across each load member is the full-line voltage; amperage in each member is $\sqrt{3}$ x line amps or 1.732 x amps

B. Wye--Amperage in each member is full-line amperage; voltage across each member is $\sqrt{3}$ x line volts or 1.732 x line volts

(NOTE: To find the power in delta or wye circuits use the formula $P = I \times \sqrt{3} \times E$.)

EXAMPLE: A three-phase circuit has 10 amperes measured on each line. The voltage is 480 volts. It is not known whether the circuit is delta or wye. What is the power of the circuit?

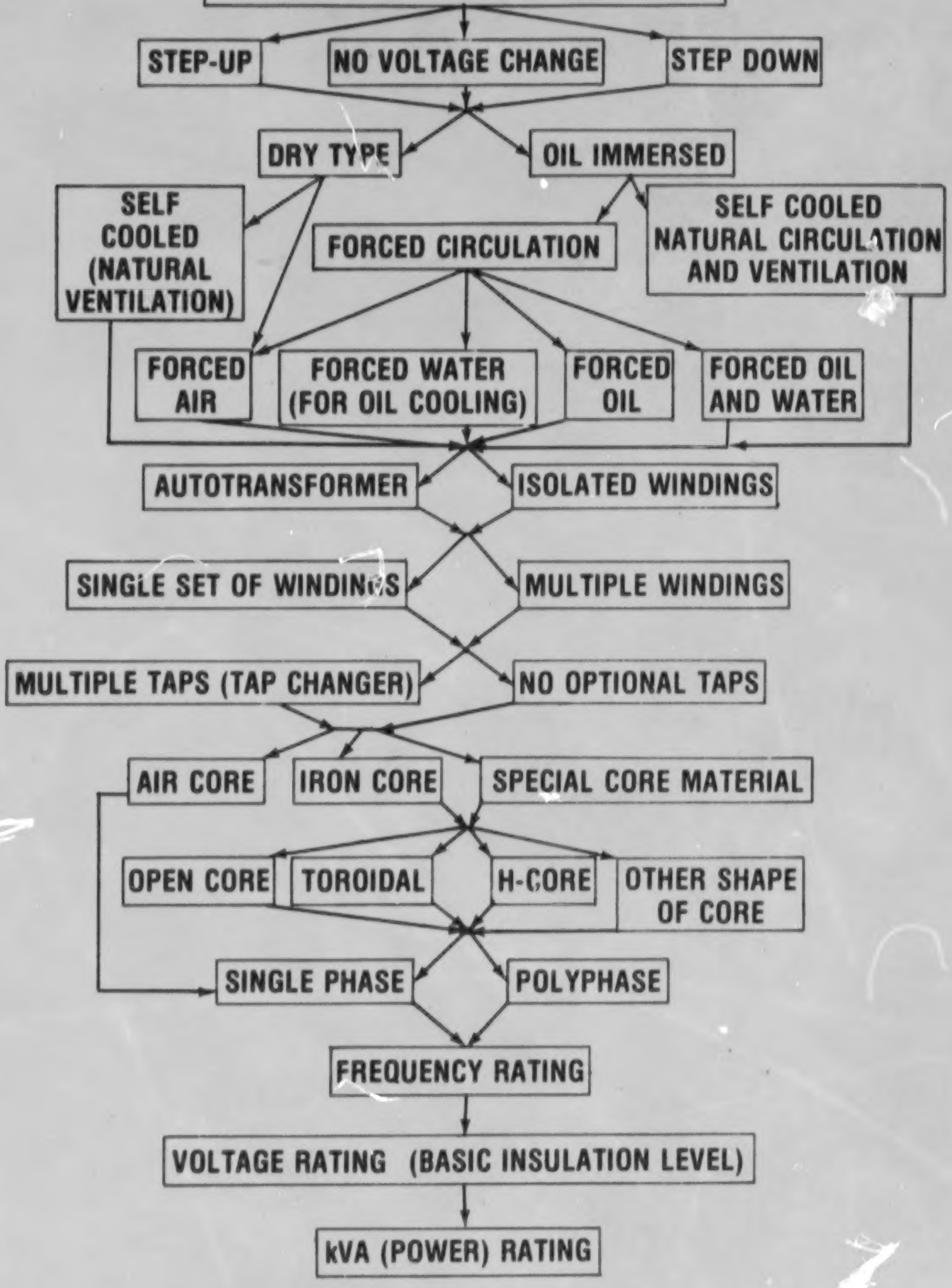
Solution: $P = I \times \sqrt{3} \times E$

$= 10 \times 480 \times 1.732$

$= 8{,}314$ VA

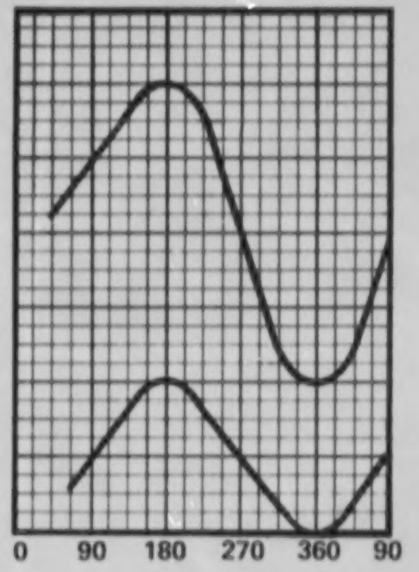
$= 8.3$ kVA

Types of Transformers


STEP-UP
NO VOLTAGE CHANGE
STEP DOWN
DRY TYPE
OIL IMMERSED
SELF COOLED (NATURAL VENTILATION)
FORCED CIRCULATION
SELF COOLED NATURAL CIRCULATION AND VENTILATION
FORCED AIR
FORCED WATER (FOR OIL COOLING)
FORCED OIL
FORCED OIL AND WATER
AUTOTRANSFORMER
ISOLATED WINDINGS
SINGLE SET OF WINDINGS
MULTIPLE WINDINGS
MULTIPLE TAPS (TAP CHANGER)
NO OPTIONAL TAPS
AIR CORE
IRON CORE
SPECIAL CORE MATERIAL
OPEN CORE
TOROIDAL
H-CORE
OTHER SHAPE OF CORE
SINGLE PHASE
POLYPHASE
FREQUENCY RATING
VOLTAGE RATING (BASIC INSULATION LEVEL)
kVA (POWER) RATING

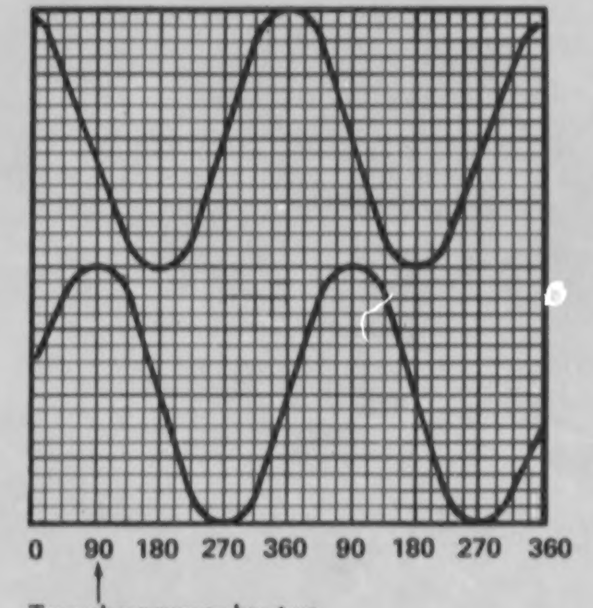
Voltage Waveforms

Single-phase



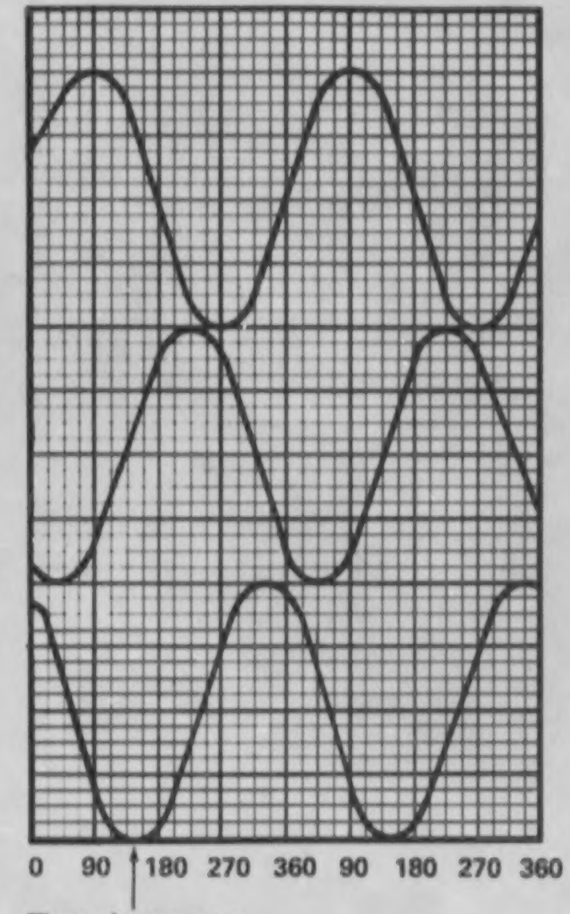
Single-phase power may contain several voltages on several wires, but they all peak at the same time.

Two-phase



Two-phase power has two voltage waveforms that peak 90% apart.

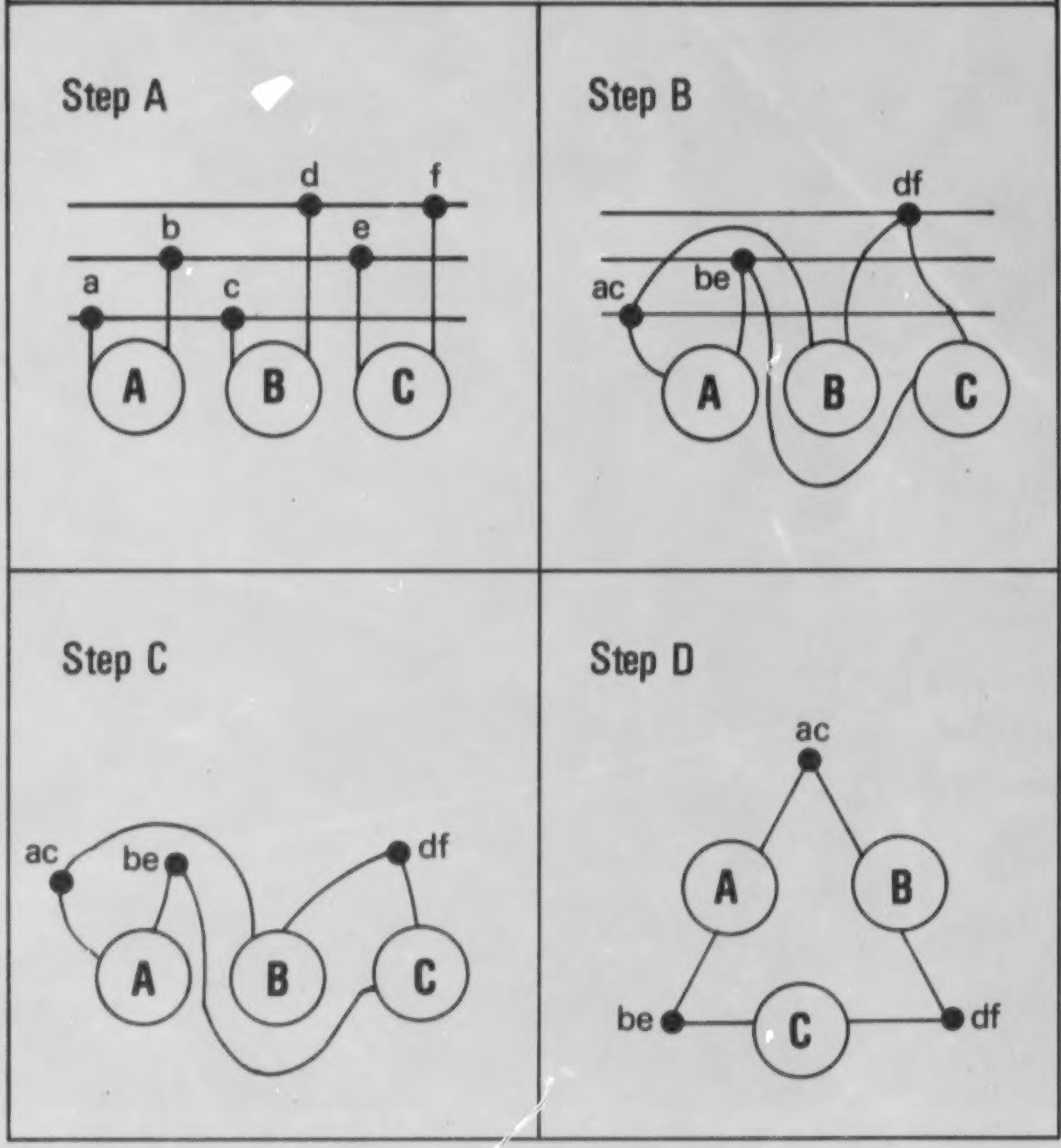
Three-phase



Three-phase power has voltages that peak each 120°.

Procedure for Identifying Three-Phase Connections

Example A



Step A

Step B

Step C

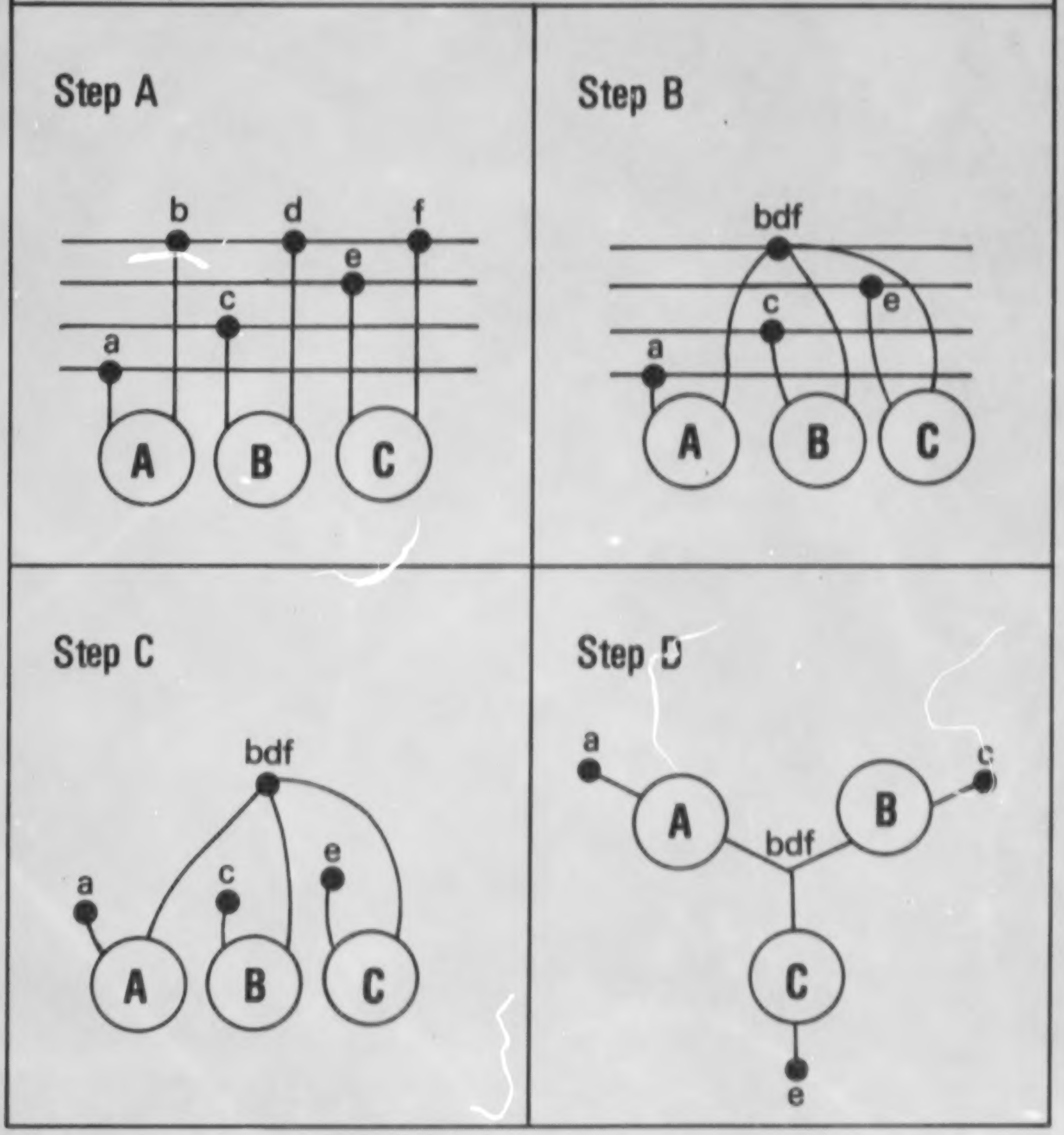
Step D

a
b
c
d
e
f
A
B
C
ac
be
df
A
B
C
ac
be
df
A
B
C
ac
A
B
be
C
df

Procedure for Identifying Three-Phase Connections

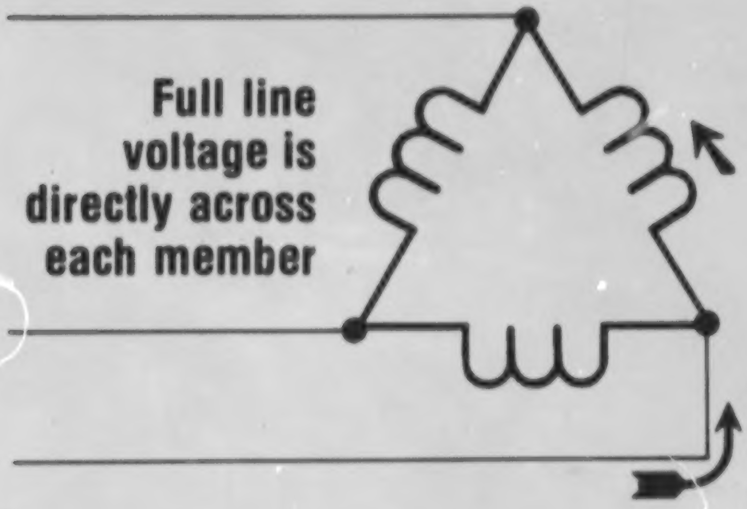
(Continued)

Example B


Step A
b
d
f
e
c
a
A
B
C
Step B
bdf
c
e
a
A
B
C
Step C
bdf
a
c
e
A
B
C
Step D
a
c
A
B
bdf
C
e

Three-Phase Voltage, Current, and Power

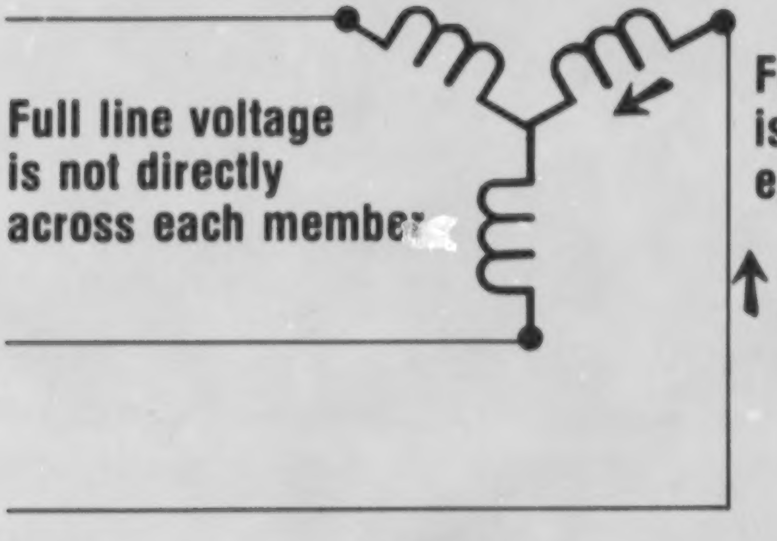
Delta



Full line voltage is directly across each member

Full-line amperage is not through each member

Wye



Full line voltage is not directly across each member

Full-line current is through each member

TRANSFORMERS
UNIT IV

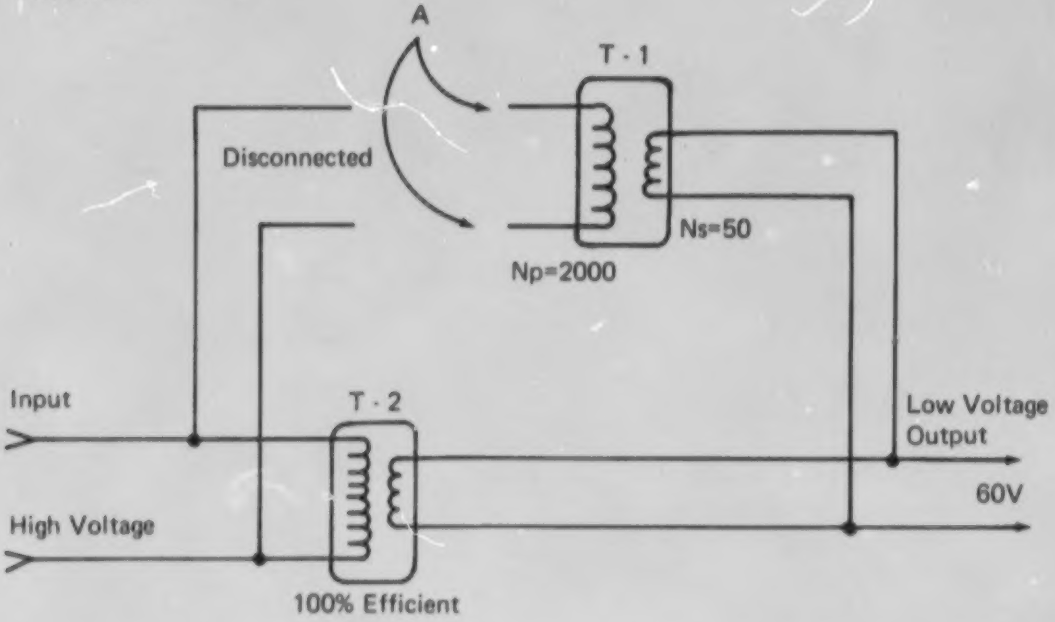
ASSIGNMENT SHEET #1--CALCULATE TRANSFORMER POWER, VOLTAGE, AND CURRENT

NAME ______________________________ SCORE ______________

If two transformers are connected in parallel, and one transformer has its input completely disconnected, there will be danger in touching those disconnected input wires. Transformers function in reverse: what was a step-down transformer may act as a step-up transformer. This is called *backfeeding* and it can be dangerous if overlooked.

Work the problems according to the circuit in Figure 29. Write your answers in the spaces provided.

FIGURE 29


A
T - 1
Disconnected
Ns=50
Np=2000
Input
T - 2
Low Voltage Output
60V
High Voltage
100% Efficient

A. Voltage = ______________________________

B. If the current input into transformer T-2 is 1 ampere, what is the power input to the circuit as shown?

Power input = ______________________________ VA

C. What is the current flow in the 60 volt circuit?

Current flow = ______________________________ A

ASSIGNMENT SHEET #1

D. If transformer T-2 is rated at 2.2 kVA, does transformer T-1 need to be connected to help handle the load? ______________________

E. If transformer T-1 is reconnected and it is identical to transformer T-2, what power will be conveyed by each transformer?

T-1 power = ______________________________________ VA

T-2 power = ______________________________________ VA

TRANSFORMERS
UNIT IV

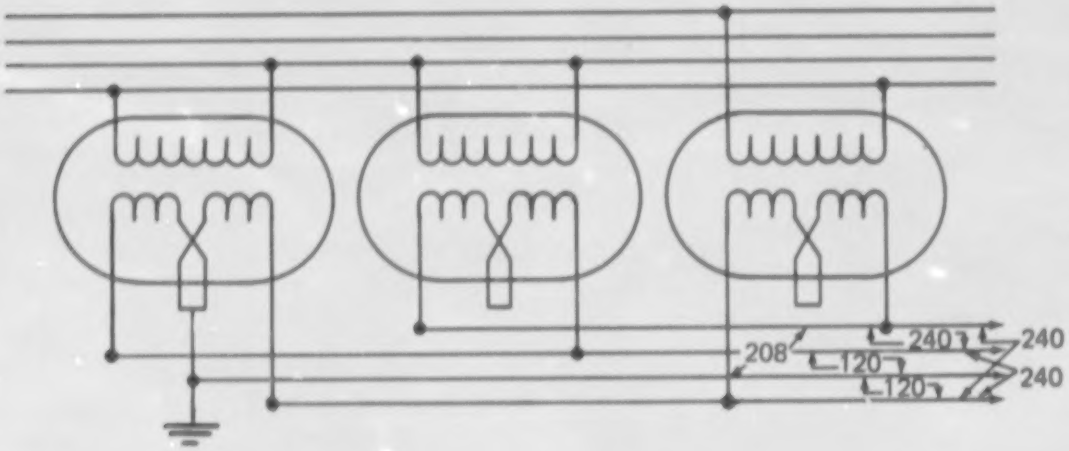
ASSIGNMENT SHEET #2--FIND FAULTS IN TRANSFORMER WIRING DIAGRAMS

NAME ______________________________ SCORE ______________

Electricians and technicians wire circuits according to a blueprint, a schematic, a set of instructions, or their own plan or mental picture. It is therefore necessary for technicians and electricians to recognize faults in wiring plans to avoid injuring personnel or damaging equipment. Miswired transformers can not only cause electrical shock, but they can explode violently.

In the diagrams that follow (Figures 30-34), find and correct the wiring errors by "X-ing" out wires that should not be in the circuit and "dashing" in wires that should be included in order to give the voltage situation described for each circuit. Do not refer to any other material.

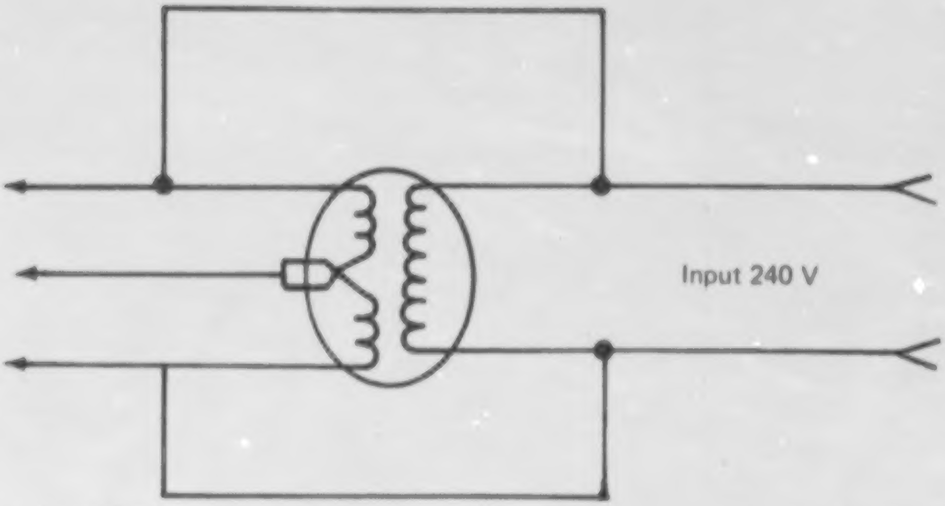
FIGURE 30



CIRCUIT A
3Ø, 4-wire, 120/240 V, ΔΔ

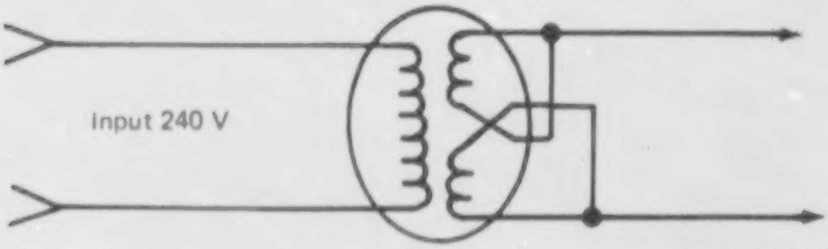
ASSIGNMENT SHEET #2

FIGURE 31



CIRCUIT B
1ϕ, 3-Wire, 120/240 V

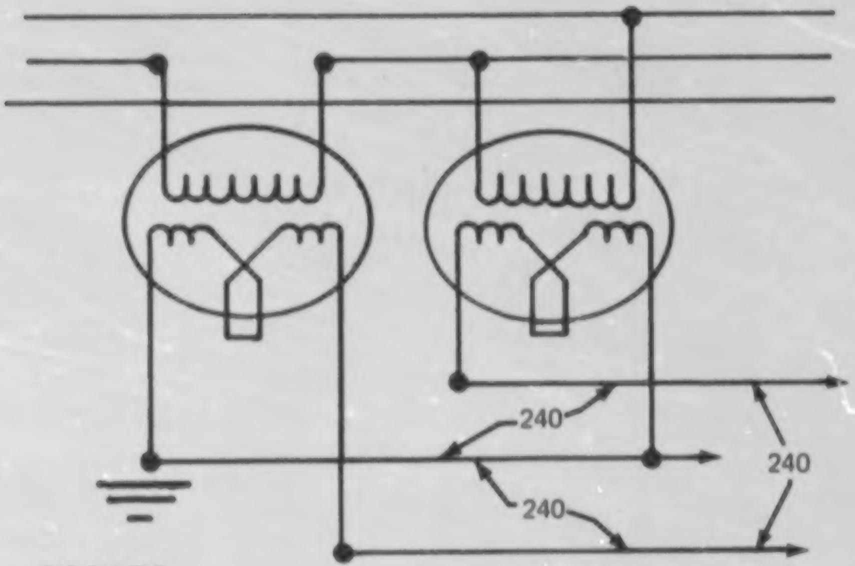
FIGURE 32



CIRCUIT C
1ϕ, 240 V

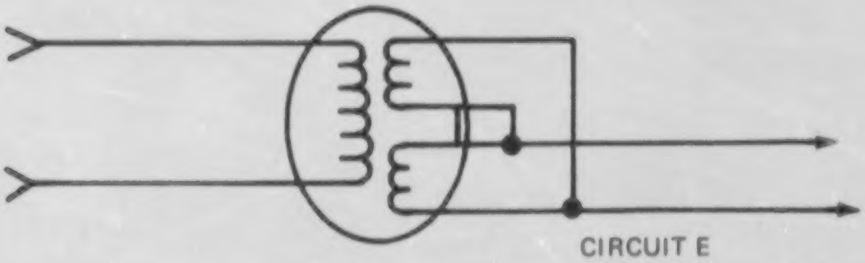
ASSIGNMENT SHEET #2

FIGURE 33



CIRCUIT D
3ϕ, 3-Wire, 240 V

FIGURE 34



CIRCUIT E
1ϕ, 120 V, Paralleled secondaries

TRANSFORMERS
UNIT IV

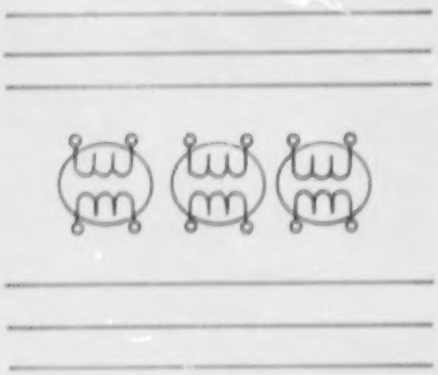
ASSIGNMENT SHEET #3--DIAGRAM TRANSFORMER CONNECTIONS FOR THREE-PHASE POWER

NAME______________________________ SCORE ______________

Three-phase power is usually connected either in delta or wye; thus, the primaries of three transformers could be either delta or wye connected, and the secondaries could be connected in either delta or wye, making four possible arrangements: delta-delta, delta-wye, wye-delta, or wye-wye.

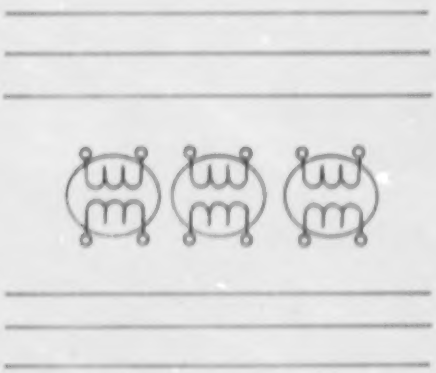
For each of the sets of transformers in the following wiring diagrams (Figures 35-38), pencil in connections to make the arrangements indicated. Do not refer to any other material.

FIGURE 35



A. Connect the transformers in Figure 35 in DELTA-DELTA

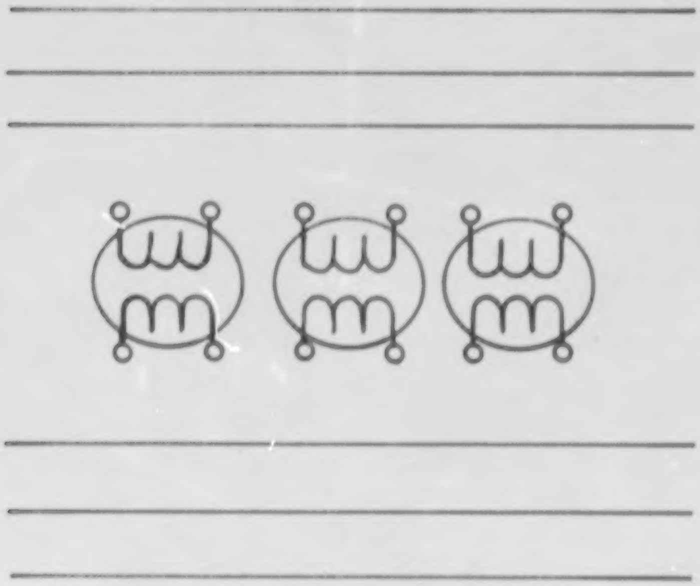
FIGURE 36



B. Connect the transformers in Figure 36 in DELTA-WYE

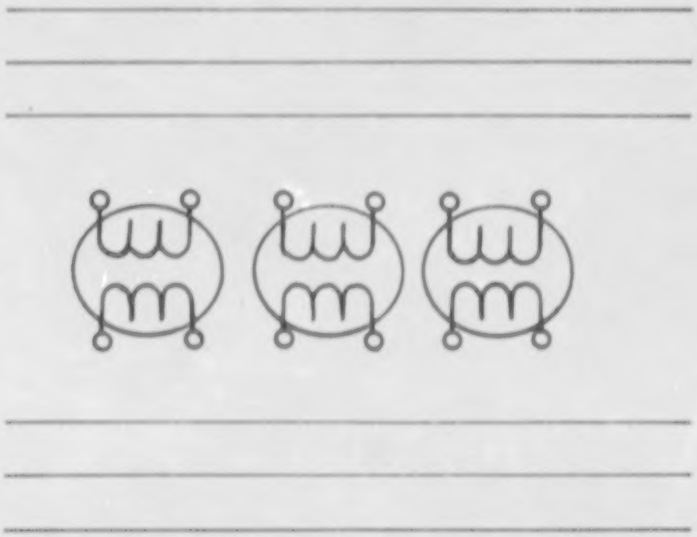
ASSIGNMENT SHEET #3

FIGURE 37



C. Connect the transformers in Figure 37 in WYE-WYE

FIGURE 38



D. Connect the transformers in Figure 38 in WYE-DELTA

TRANSFORMERS
UNIT IV

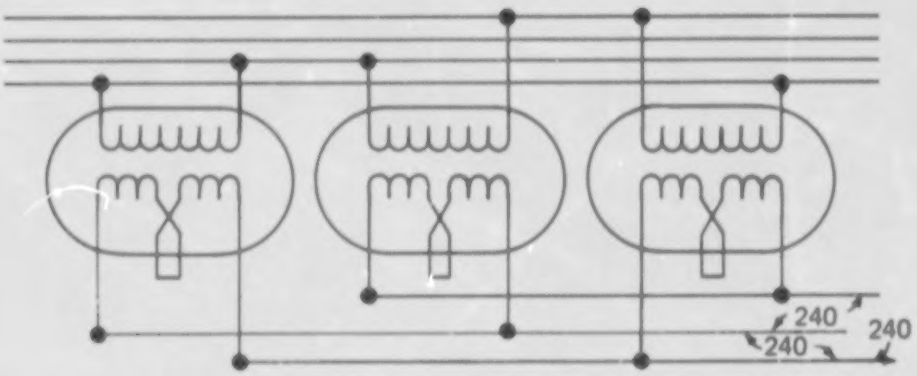
ASSIGNMENT SHEET #4--IDENTIFY TYPES OF TRANSFORMER CONNECTIONS

NAME ____________________ SCORE ____________

Three-phase power circuits are found throughout industry in various forms for many applications. Within a single factory, several different connections may exist. A qualified electrician must be able to read plant wiring prints and recognize the various connections in order to properly connect electrical equipment so that it will function safely, efficiently, and without damage.

Identify the following transformer connections (Figures 39-44). Some are delta primaries, some are wye primaries. The secondaries are mixed also. Write your answers in the spaces below each diagram.

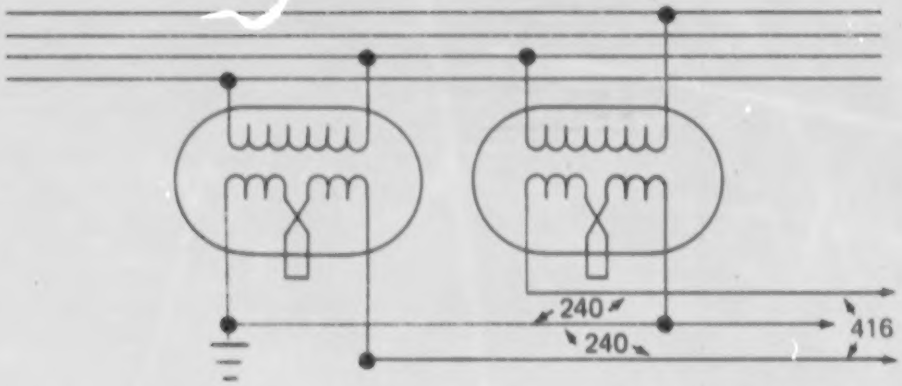
FIGURE 39



A. ____

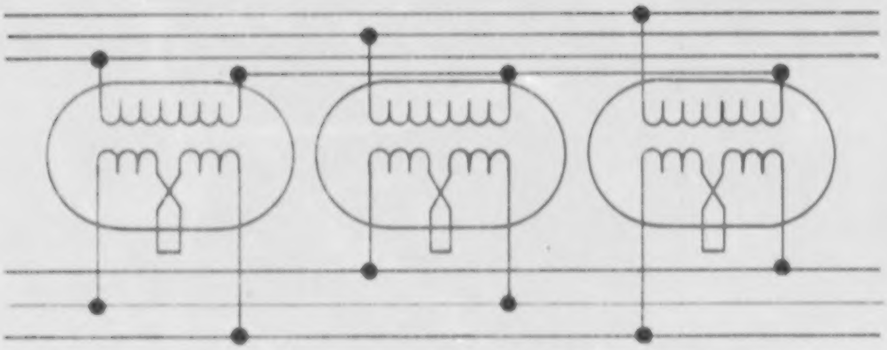
ASSIGNMENT SHEET #4

FIGURE 40



B. ______________________________

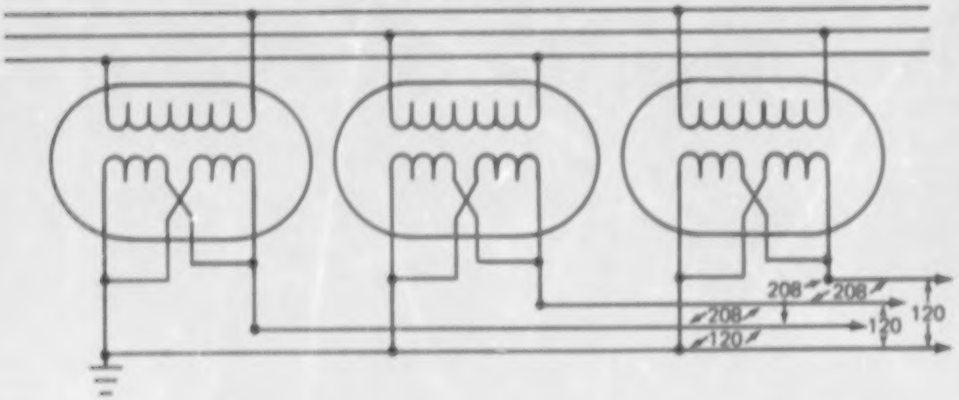
FIGURE 41



C. ______________________________

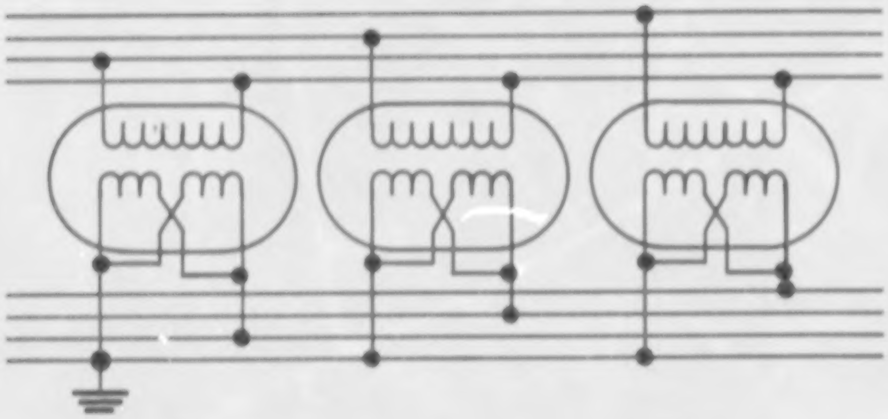
ASSIGNMENT SHEET #4

FIGURE 42


208
208
208
120
120
120

D. ______________________________

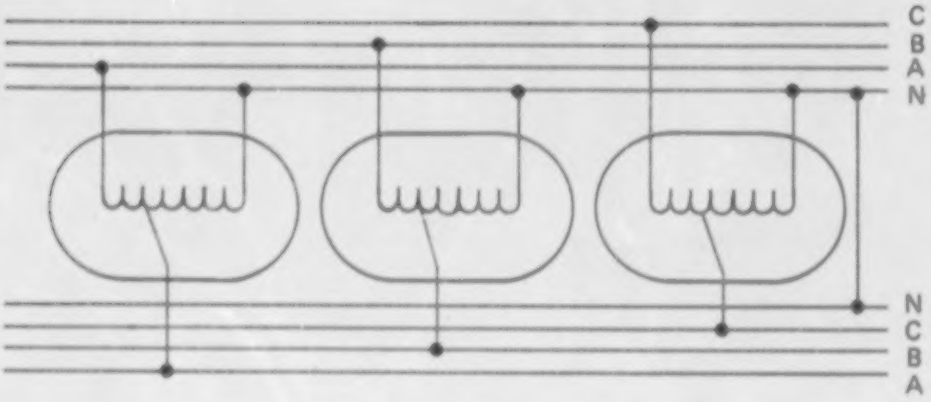
FIGURE 43



E. ______________________________

ASSIGNMENT SHEET #4

FIGURE 44



F. ____

TRANSFORMERS
UNIT IV

ASSIGNMENT SHEET #5--CALCULATE POWER IN THREE-PHASE CIRCUITS

NAME ______________________________ SCORE ______________

Power in three-phase circuits is not as obvious as it might seem. The total power is not the sum of the power measured in each wire. This is because the three wires share current or voltage, and if they are measured for each wire they will be counted more than once. Total power is not *three times* the power of one wire, but *1.732* times the power of one wire.

Calculate the power in each of the following problems.

A. A three-phase, wye-connected motor has 5 amperes measured in each lead wire. The motor is rated at 460 volts, but a measurement of the phase-to-phase voltage shows 480 volts. What power is the motor requiring?

Power = ______________________________ VA

B. A three-phase, delta-connected heater is operating at 240 volts. Each element of the three elements was measured at 60 ohms when the power was off and they were disconnected. It is assumed that their resistance does not change during operation. What is the power of the heater?

(NOTE: Use Ohm's Law to find the current.)

Power = ______________________________ VA

TRANSFORMERS
UNIT IV

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 2,400 V

B. Any of the following units

2,400 W; 2,400 VA; 2.4 kVA; 2.4 kW

C. 40 A

D. Yes (T-2 is overloaded at 2.4 kVA)

E. Any of the following units

1,200 W; 1,200 VA; 1.2 kVA; 1.2 kW

Assignment Sheet #2--See the following drawings

Assignment Sheet #3--See the following drawings

Assignment Sheet #4

A. Three-wire, 240 volts, delta-delta

B. Three wire, 240/416 volts, open delta, open wye

C. Three-wire, wye-delta

D. Four-wire, 120/208 volts delta-wye

E. Four-wire, wye-wye

F. Four-wire, autotransformer, wye-wye

Assignment Sheet #5

A. 4,157 VA

B. 1,663 VA

ANSWERS TO ASSIGNMENT SHEETS

FIGURE 30

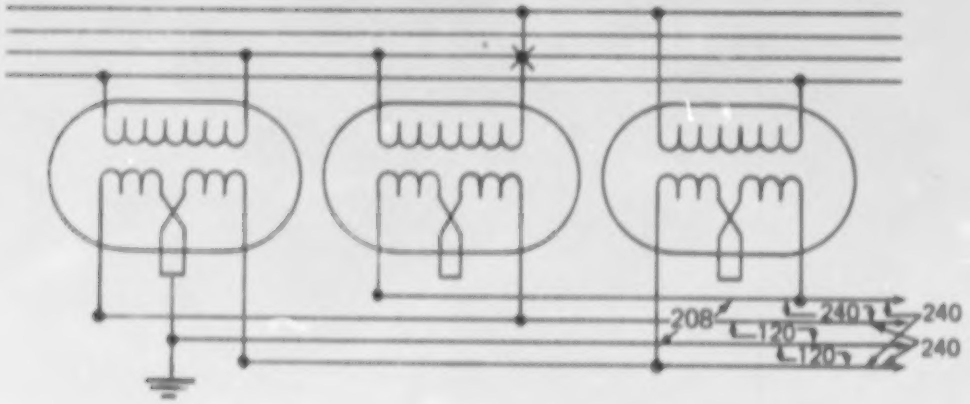

208
240
120
120
240
240

FIGURE 31

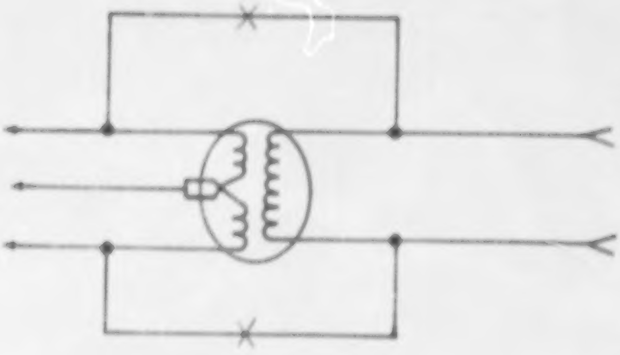


FIGURE 32

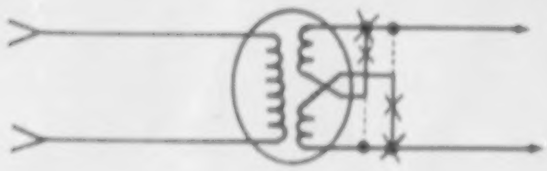


FIGURE 33

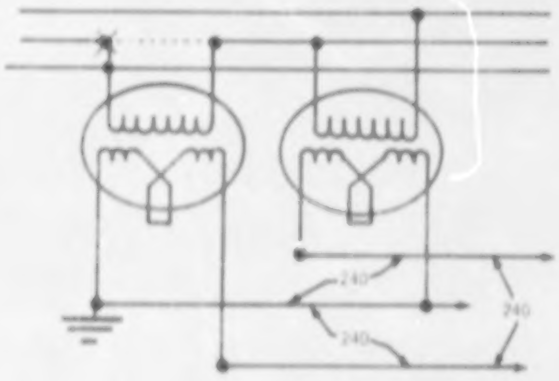
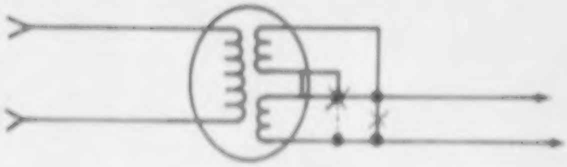


FIGURE 34

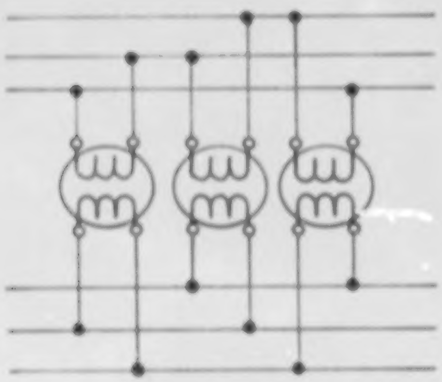


ANSWERS TO ASSIGNMENT SHEETS

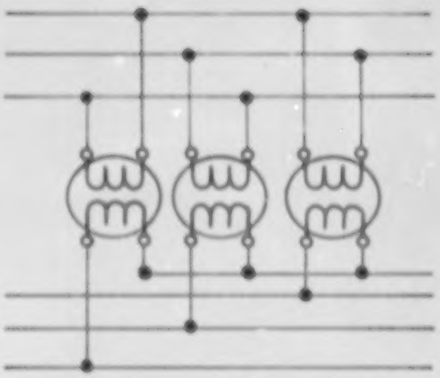
Assignment Sheet #3

(NOTE: Correct arrangements may vary slightly.)

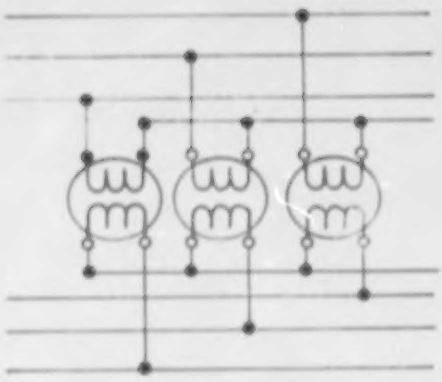
A.



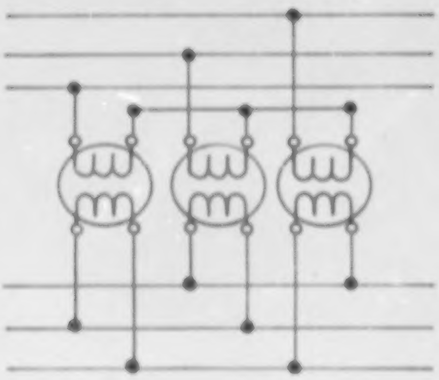
B.



C.



D.



TRANSFORMERS
UNIT IV

JOB SHEET #1–CHECK TRANSFORMER POLARITIES WITH A VOLTMETER

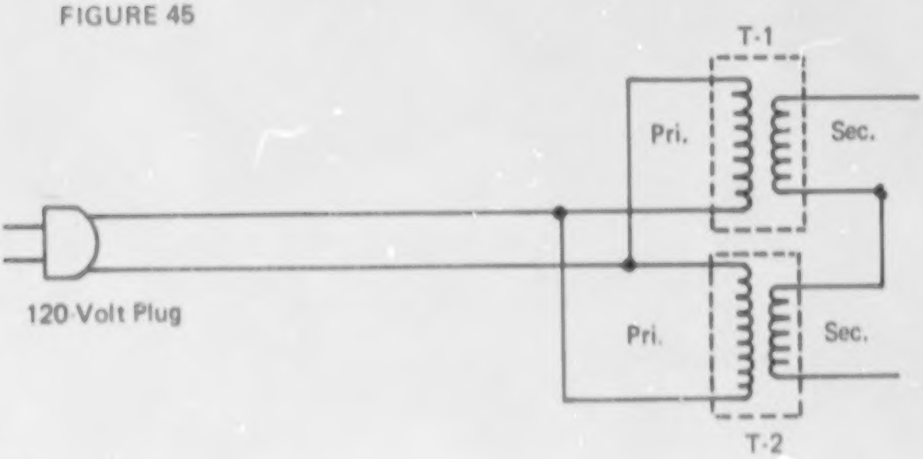
I. Equipment and materials

- A. Multimeter
- B. Transformers–Two, 60 hertz, single phase, 120 or 240 volt primary with 120 volts or less, single secondary; small power, such as control circuit transformers
- C. Test leads
- D. Wire nuts, if transformers with lead wires are to be used
- E. 120 VAC plug for primary power connection with two lead wires extended

II. Procedure

- A. Set controls of the voltohmmeter or multimeter for ohms measurement at a high scale
- B. Measure both transformers to verify a low ohms reading between primary leads, a low ohms reading between secondary leads, an infinite reading between primary and secondary leads, and an infinite reading from both secondary and primary leads to the metal parts of the exposed core or case
- C. Connect the 120-volt plug to the two transformer primaries in parallel (Figure 45)
- D. Connect one secondary lead from each transformer as shown in Figure 45

FIGURE 45



JOB SHEET #1

E. Connect the two remaining secondary leads to the voltmeter

F. Set voltmeter controls for AC volts with full-scale at a scale higher than *twice* one transformer secondary

(NOTE: Have instructor check your circuit.)

G. Plug in the circuit

H. Take the voltmeter reading

I. Record the voltage in the space below

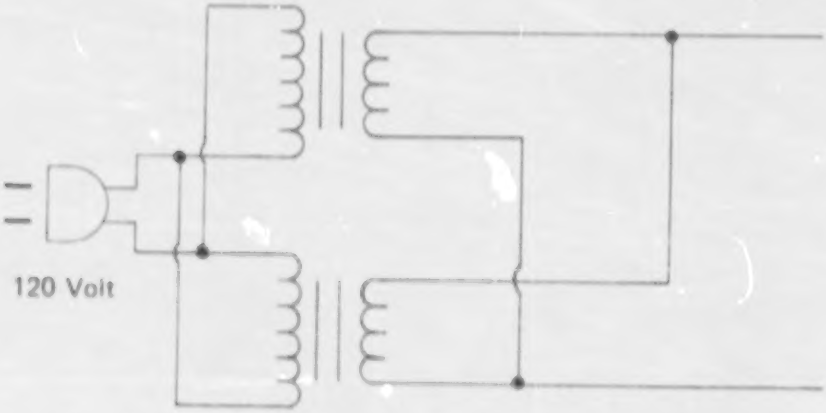
Voltage = ______________________________

J. Unplug the circuit

K. Unhook the secondary leads from both transformers

L. Connect both secondary leads from each transformer to the same secondary leads of the second transformer (Figure 46)

FIGURE 46



M. Connect the voltmeter to the two transformer leads shown in Figure 46

(NOTE: Have instructor check your circuit.)

N. Plug in the circuit

O. Record the voltage

Voltage = ______________________________

JOB SHEET #1

P. Unplug the circuit

(NOTE: The circuit that showed a low voltmeter indication is the proper method of paralleling the two transformer secondaries. The circuit that showed a high voltmeter indication is the proper method of connecting two transformers in series. Show your sketch to the instructor.)

Q. Put equipment and materials away

TRANSFORMERS
UNIT IV

JOB SHEET #2--EXAMINE THE FREQUENCY RESPONSE OF A TRANSFORMER

I. Equipment and materials

A. Multimeter

B. Signal generator or audio oscillator--Output capability from at least 30 Hz to 400 Hz sine wave, with test leads

C. Transformer--120 VAC primary, 60 Hz, low voltage secondary, e.g. a 24-volt control transformer

D. Resistor--200 ohms, 1 watt or greater

E. Appropriate test leads to connect resistor to transformer secondary

II. Procedure

A. Connect transformer primary to the signal generator output

B. Connect the 200-ohm resistor to the transformer secondary

C. Adjust the signal generator output controls for about 60 hertz

D. Adjust the output level control to minimum

E. Connect the voltmeter across the generator output leads (across the primary of the transformer)

F. Set the voltmeter controls for AC operation at a voltage level of 24 volts

G. Turn on the signal generator

H. Adjust the output level to about one-half maximum but not more than 24 volts

I. Select a lower voltage scale on the voltmeter for a reading near center scale if the generator has a lower output than 12 volts, or select a reading to within one-tenth of a volt if a digital meter is used

J. Adjust the generator output for a specific voltage (40 volts, 15 volts, 12 volts, etc.) that will be the reference

K. Move the voltmeter connections so that they are across the transformer output

L. Read the output for 60 hertz, and record in the space provided at the end of the job sheet

JOB SHEET #2

M. Move the voltmeter leads back to the primary

N. Adjust the frequency down 10 hertz to 50 hertz

O. Adjust the output, if necessary, so that the reference voltage is the same as it was in Step J

P. Move the voltmeter leads back to the transformer secondary

Q. Read and record the output for 50 hertz

R. Repeat steps M, N, O, P, and Q for frequencies from 20 hertz to 200 hertz

(NOTE: If the output voltage readings are the same for all input frequencies, repeat the procedure while making more precise measurements by changing voltmeter scales if necessary. Show the data to your instructor.)

S. Put tools and materials away

FREQUENCY (HERTZ)	VOLTAGE OUTPUT
20	
30	
40	
50	
60	
70	
80	
90	
100	
120	
140	
160	
180	
200	

TRANSFORMERS
UNIT IV

JOB SHEET #3–SET UP TRANSFORMER BACKFEED IN A PARALLEL CIRCUIT

I. Equipment and materials

A. Multimeter

B. 120 VAC plug wired to two test leads

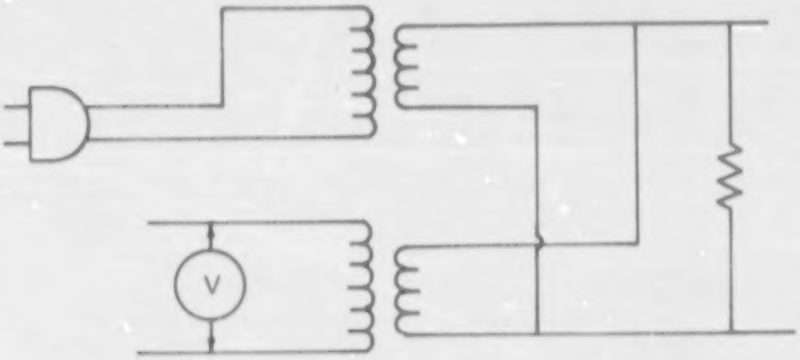
C. Transformers–Two with 120 VAC primaries, 24 VAC, secondaries, 60 Hz, control transformers, and secondaries rated at 1/20 ampere or more

D. Resistor–500-ohm, 1 watt or more

II. Procedure

A. Connect the 120-volt plug, the two transformers, and the resistor, as indicated in Figure 47

FIGURE 47



B. Connect the voltmeter across the second transformer's primary leads

C. Set the voltmeter for AC operation at 120 volts

(NOTE: Have the instructor check your circuit.)

D. Plug in the circuit and read the voltage on the meter

(NOTE: This is backfeed from the secondary to the primary.)

E. Record the voltage

Voltage = ______________________________

JOB SHEET #3

F. Unplug the circuit and disconnect resistor, but leave the transformer secondaries connected

(NOTE: Have the instructor re-inspect your circuit.)

G. Plug in the circuit

H. Read and record the voltage

Voltage = ______________________________

I. If the transformers were operating with 2400-volt primaries and 120-volt secondaries, what voltage would be backfed?

Backfed voltage = ______________________________

(NOTE: Show your work to the instructor.)

J. Put equipment and materials away

TRANSFORMERS
UNIT IV

JOB SHEET #4--DETERMINE THE CONFIGURATION OF A MULTIPLE-WINDING TRANSFORMER

I. Equipment and materials

A. Multimeter

B. Voltmeter (or multimeter used above) with test leads

C. DC power supply, or DC source (battery)--12 to 24 volts, with test leads

D. Variac, or variable AC supply--60 Hz, from 20 to 120 volts, with test leads

E. Multiple winding transformer with diagram covered with paint or removed--60 Hz, 120- to 240-volt primary, step-down secondaries, wire leads attached

F. Wire markers (numbered tape markers)--At least half as many as the number of transformer connections

II. Procedure

A. Use wire markers to mark each transformer lead wire

(NOTE: Use a number "2" and a number "10" to make 210, etc. Each wire should have a different number or a different pair of numbers.)

B. Use the ohmmeter to identify which wires are interconnected

JOB SHEET #4

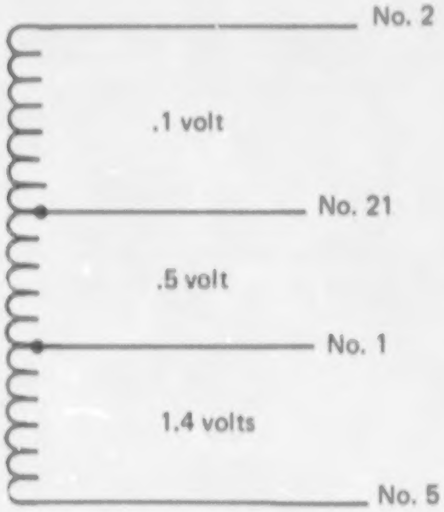
C. Record the numbers in groups as shown in Figure 48

EXAMPLE:

FIGURE 48

Group C:

No. 2
No. 1
No. 21
No. 5


No. 2
.1 volt
No. 21
.5 volt
No. 1
1.4 volts
No. 5

No. 2 to No. 21	.1V
No. 2 to No. 1	.6 V
No.2 to No. 5	2V
No. 21 to No. 1	.5V
No. 1 to No. 5	1.4V
No. 21 to No. 5	1.9V

JOB SHEET #4

D. Connect the transformer to the AC supply or variac by connecting it to the group that has only one pair, the heaviest insulation, is color-coded black, or is the most removed from the other leads

(NOTE: This is probably the primary input.)

E. Separate the wires so that their leads do not touch

F. Turn the AC supply output control down to the minimum

G. Turn on the power, adjusting the AC supply output for 20 volts

(NOTE: Use the voltmeter if the supply does not have a panel meter.)

H. Use voltmeter to measure between wires within each group

I. If any pair produces a reading of more than 20 volts, reconnect the power supply to that pair

J. Remeasure and record the voltage between each pair with each group as shown in Figure 48

K. Sketch each group from voltage readings

(NOTE: The two having the highest readings are the outside ends of the windings; other measurements should be parts of that total voltage.)

JOB SHEET #4

L. Disconnect the AC supply

M. Connect one primary lead to the DC supply

N. Answer the following questions:

1. Do transformers operate on DC power?

   ____

   ____

2. If AC is constantly changing, is it significant to assign a polarity relationship to transformer windings?

   ____

   ____

O. Connect the voltmeter between a pair of leads representing the ends of a winding

P. Set the controls for 24 volts DC

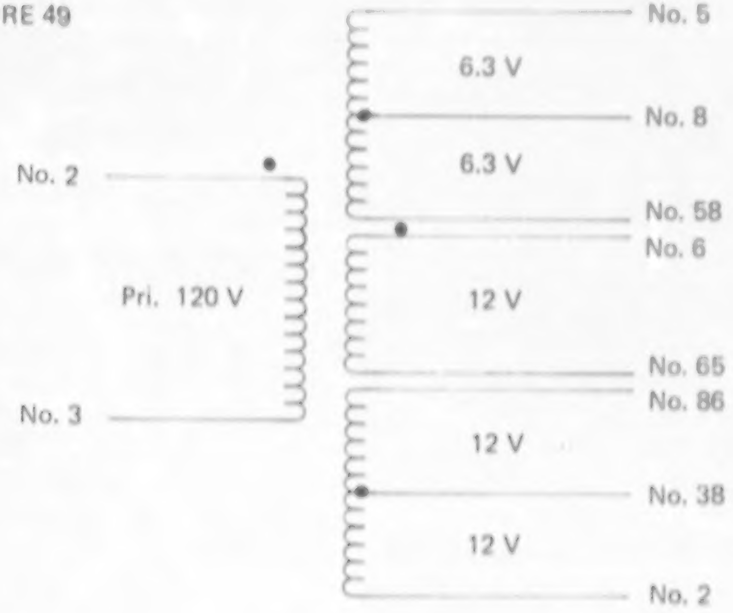
Q. Turn on the DC supply and briefly touch the remaining transformer primary lead to the other DC supply output terminal making contact for only a split second while watching the voltmeter

JOB SHEET #4

R. If the voltmeter deflects toward upper scale (positive flash for digital meters), return to the sketches you made in Step K, and draw in and mark with a large dot next to the number, the transformer lead connected to the positive voltmeter lead as shown in Figure 49

(NOTE: These dots are referred to as *polarity markings* and are sometimes seen on schematics.)

FIGURE 49



S. Using the Step K sketches, draw and mark with a large dot, the transformer lead connected to the negative voltmeter lead, if the meter indication tends to go off scale or negative

T. Continue with steps Q, R, and S for each set of secondary end leads

U. Using the Step K sketches, draw in the transformer primary

V. Mark a large dot next to the lead connected to the positive terminal of the D.C. supply

JOB SHEET #4

W. Resketch the transformer making all dot-marked leads at the top of the windings as in Figure 49

X. Multiply each AC voltage reading by six, because the input was only 20 volts in the test, or 1/6 of 120 volts

(NOTE: If the transformer has a 240-volt primary, multiply each voltage reading by twelve.)

Y. Record the voltages on the new transformer sketch

(NOTE: Show your sketch to the instructor.)

Z. Put equipment and materials away

TRANSFORMERS
UNIT IV

JOB SHEET #5--CHECK A TRANSFORMER USING AN INSULATION TESTER

I. Equipment and materials

A. Insulation tester ("Megger")

B. Instruction booklet or operation manual for particular insulation tester to be used

C. Transformer--Rated at 240 volts or more

(CAUTION: Do not attempt to complete this job sheet unless you have operated an insulation tester before, or unless your instructor has demonstrated the proper use of the instrument you are to use. Insulation testers produce high voltages that can cause injury or death.)

II. Procedure

A. Read instructions for operating insulation tester

B. Connect tester leads to one primary terminal and ground

C. Select the next voltage above the transformer rating

D. Use test leads to ground secondaries

E. Operate tester according to instructions

(CAUTION: Make certain that no one is near the transformer or its connections.)

F. Record the results

____

G. Connect to and measure between each group of windings and ground, making certain that all other windings are grounded

H. Record each result

____

____

____

____

(NOTE: Show the results to your instructor.)

I. Put equipment and materials away

TRANSFORMERS
UNIT IV

TEST

NAME ______________________________ SCORE ____________

1. Match terms associated with transformers to their correct definitions. Write the correct numbers in the blanks.

_____a. Schematic diagram where one line represents other lines as well; usually represents three-hase power in power distribution systems and high voltage substations

_____b. Power lost in magnetizing metal from one direction to another

_____c. Small electrical currents that travel in circular paths within a piece of metal subjected to magnetic forces

_____d. Power distribution cable at a ground potential, but may conduct current to complete circuit

_____e. Alternating current power consisting of a single voltage waveform

_____f. Alternating current power consisting of two voltage waveforms that peak 90° apart

_____g. Alternating current power consisting of three voltage waveforms that peak 120° apart

_____h. More than one phase

_____i. Ratio of the number of turns in the primary winding to the number of turns in the secondary winding of a transformer

1. Single-phase power
2. Turns ratio
3. Hysteresis loss
4. One-line diagram
5. Two-phase power
6. Polyphase
7. Eddy currents
8. Three-phase power
9. Neutral conductor

2. Name abbreviations and symbols associated with transformers.

a. emf-- ______________________________

b. HV-- ______________________________

c. Pri-- ______________________________

d. XFMR-- ______________________________

TEST

e. kVA-- ____________________

f. VAC-- ____________________

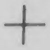
g. P-- ____________________

h. CT-- ____________________

i. I^2R-- ____________________

j. N_s-- ____________________

k. ϕ-- ____________________

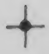
l.  -- ____________________

m. -- ____________________

n. Δ-- ____________________

o. PT-- ____________________

p. Y -- ____________________

q.  -- ____________________

r. N_p-- ____________________

s. E-- ____________________

t. W-- ____________________

u. I-- ____________________

v. kW-- ____________________

w. Sec-- ____________________

x. V-- ____________________

y. E_p-- ____________________

z. I_s-- ____________________

aa. A-- ____________________

bb. E_s-- ____________________

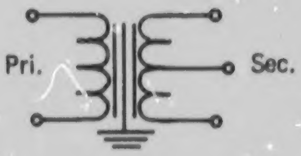
cc. I_p-- ____________________

dd. VA-- ____________________

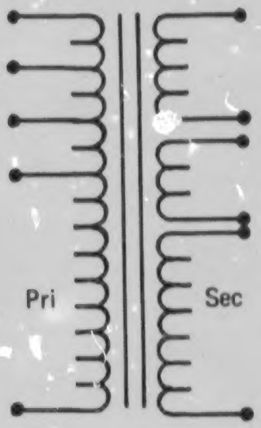
ee. VDC-- ____________________

TEST

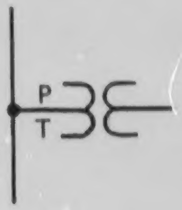
3. Label transformer circuit symbols.



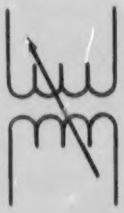
a. ______________________________



b. ______________________________

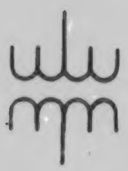


c. ______________________________

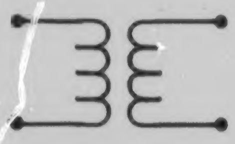


d. ______________________________

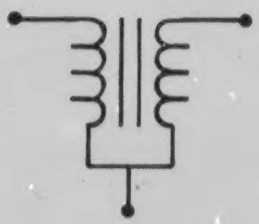
TEST

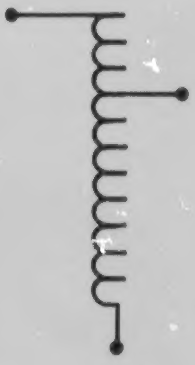


e. ____________________

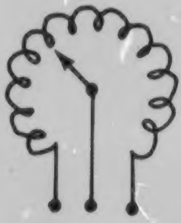


f. ____________________



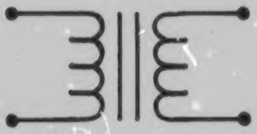


g. ____________________

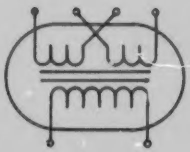


h. ____________________

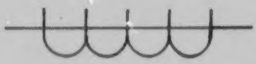
TEST



i. ____



j. ____



k. ____

4. Match types of transformers to their correct descriptions and applications. Write the correct numbers in the blanks.

_____a. Step-down transformer used to measure high voltage by stepping voltage down by a known fraction to a measurable value

_____b. Step-down transformer used to measure high current and provide isolation from high voltages; provides a fraction of current to gauge value of total current

_____c. Transformer whose primary and secondary windings are of a common core and share a common connection

_____d. Transformer having a metal core usually made of laminations of iron or steel; usually applied to low frequency, high power applications

1. Iron-core transformer
2. Potential transformer
3. Current transformer
4. Autotransformer

TEST

______ e. Transformer used to reduce voltage while often increasing current capability above that of the source

______ f. Transformer having a ring-shaped core around which windings are wrapped

______ g. Transformer without an iron or metal core; usually applied to low power, high frequency applications

______ h. Variable autotransformer that can be varied while operating

______ i. Transformer used to isolate circuits from a common ground, from direct current potentials, or to improve power transfer by impedance matching improvement, often providing no change in voltage

______ j. Transformer used to increase voltage, often while sacrificing current capability of source

______ k. High voltage transformer, usually an autotransformer; often used to develop high voltage ignition for gasoline engines and gas firing devices

______ l. Additional transformer placed in a transmission or distribution line to boost voltage to an acceptable level from a reduced level caused by line length

5. Step-down transformer
6. Toroidal transformer
7. Air-core transformer
8. Step-up transformer
9. Booster transformer
10. Variac
11. Spark coil
12. Isolation transformer

5. List types of transformer power losses.

   a. ______________________________

   b. ______________________________

   c. ______________________________

6. Discuss methods of reducing power loss in transformers.

____

____

____

____

____

TEST

7. Identify types of single-phase transformer connections. Write the correct answer in the blank below each connection.

240 volts, two-wire

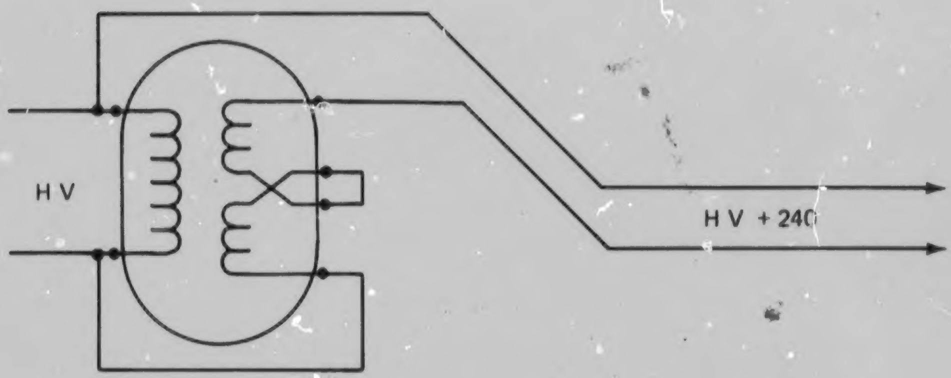
120/240 volts, three-wire

120 volts, two-wire

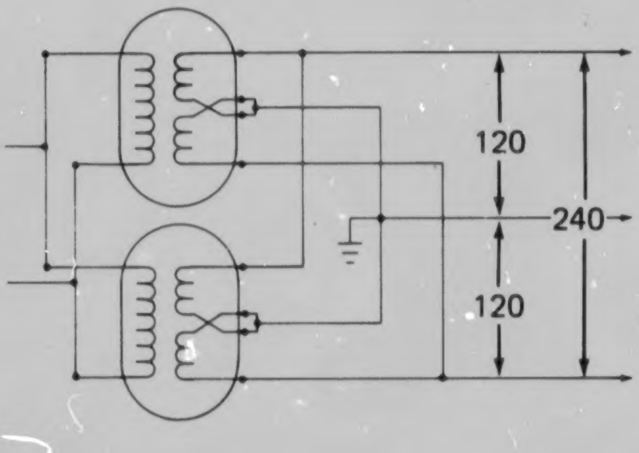
High voltage, boosted by 240 volts

120/240 volts, three-wire with additional power capacity of two transformers

208 volts, two-wire from 240 volt through autotransformer

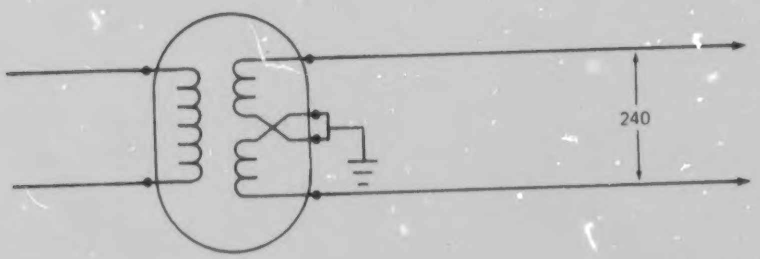


a. ____________________

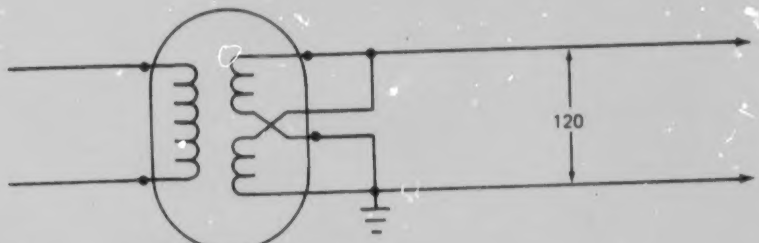


b. ____________________

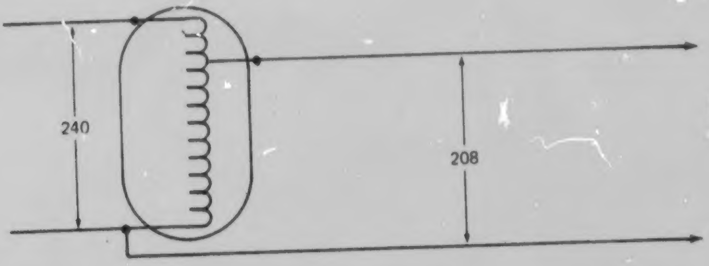
TEST



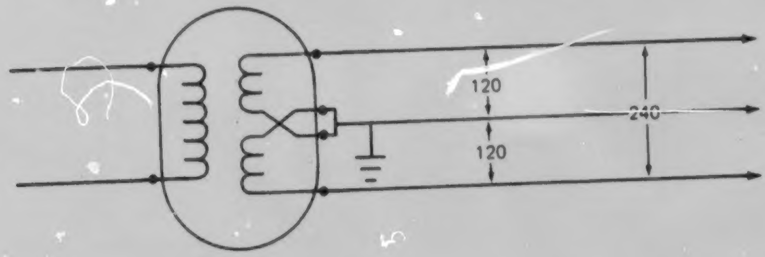
c. ______________________________



d. ______________________________



e. ______________________________

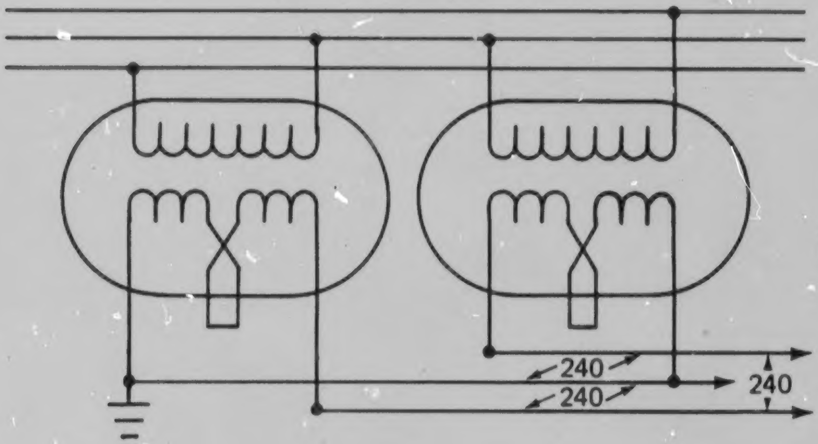


f. ______________________________

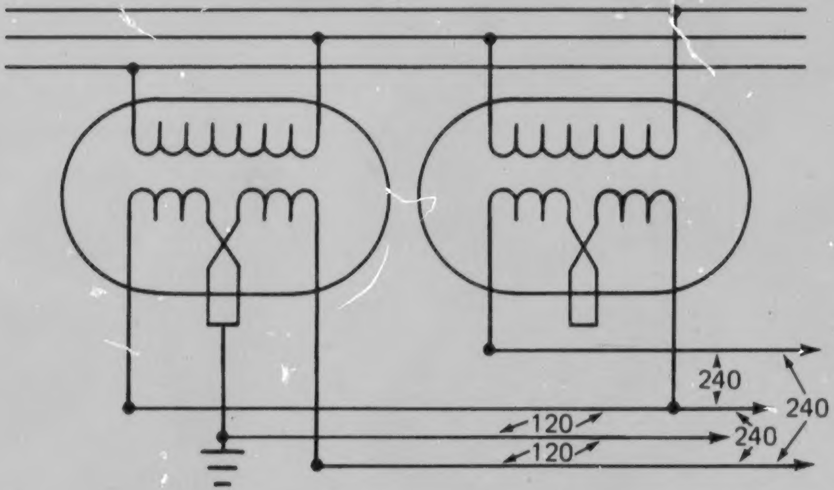
TEST

8. Identify types of three-phase transformer connections with delta-connected primaries. Write the correct answer in the blanks below each connection.

Three-wire, 240 volts, delta-delta	Four-wire, 120/240 volts, open delta
Three-wire, 240 volts, open delta	Four-wire, 120/208 volts, delta-wye
Four-wire, 120/240 volts, delta-delta	Four-wire, 277/480 volts, delta-wye

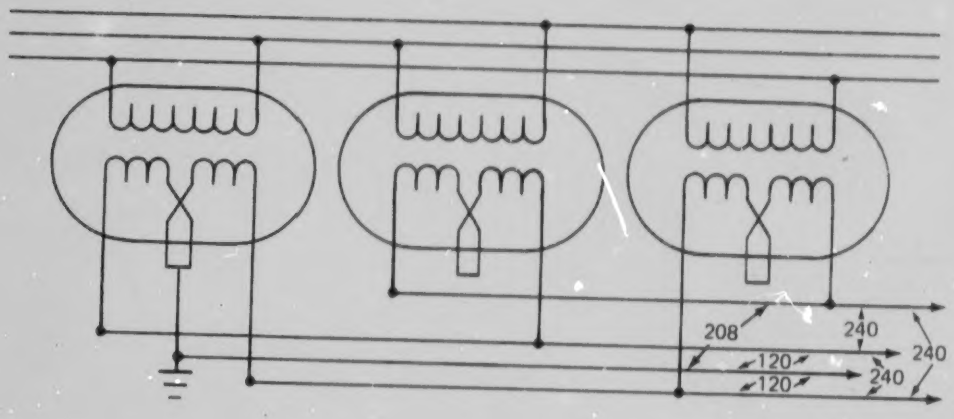


a. ______________________________

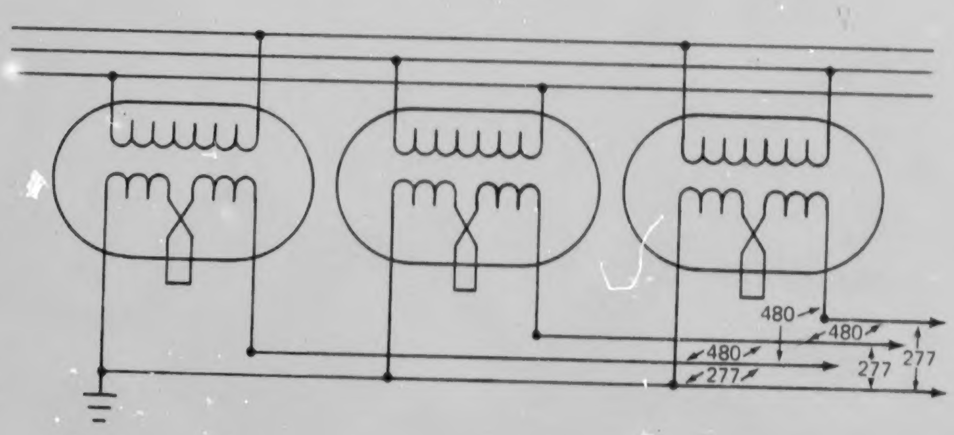


b. ______________________________

TEST

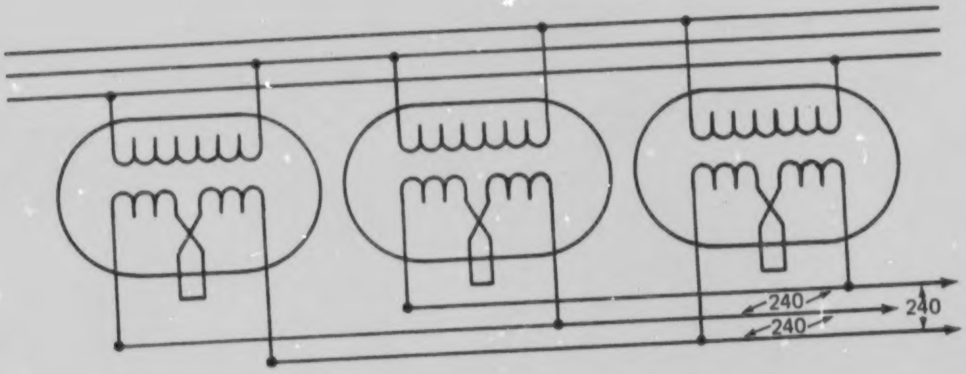

208
240
240
120
120
240

c. ____

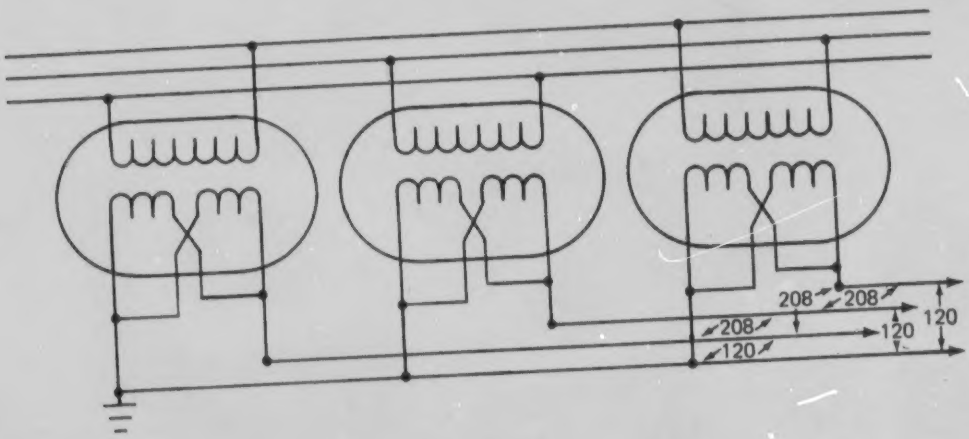

480
480
480
277
277
277

d. ____

TEST



e. ____________________


208
208
208
120
120
120

f. ____________________

TEST

9. Identify types of three-phase transformer connections with wye-connected primaries. Write the correct answer in the blank below each conection.

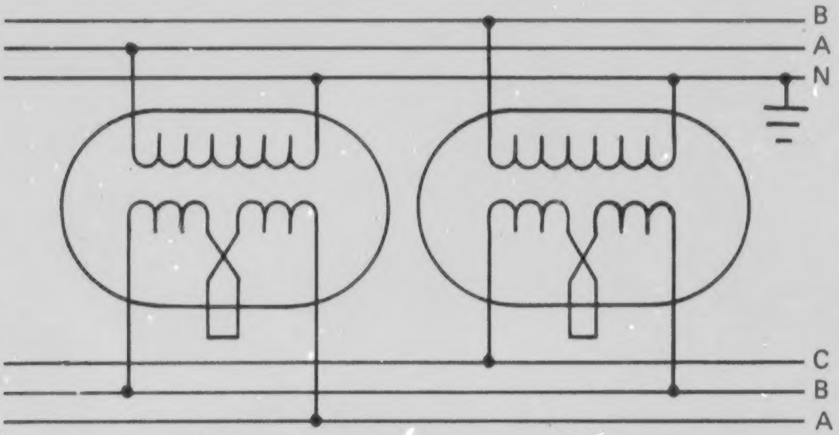
Three-wire, 240 volts, wye-delta

Three-wire, 240 volts, open wye to open delta

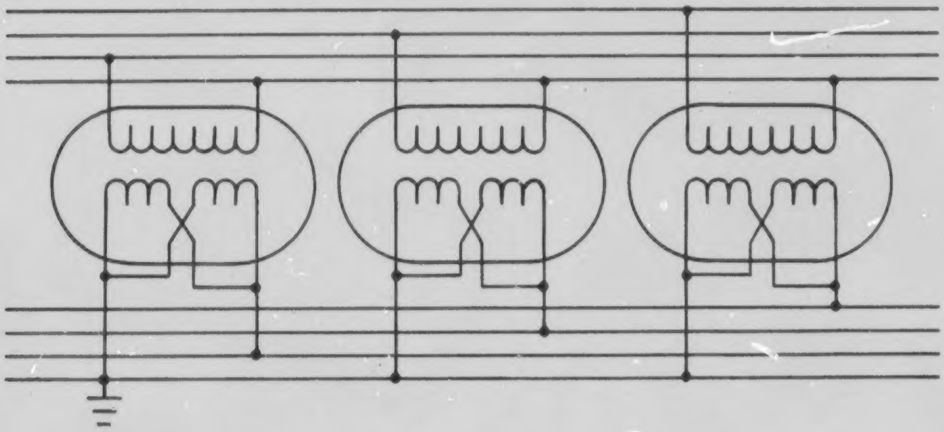
Four-wire, 120/240 volts, wye-delta

Four-wire, 120/208 volts, wye-wye

Four-wire, 240 to 208 volts, autotransformer, wye-wye

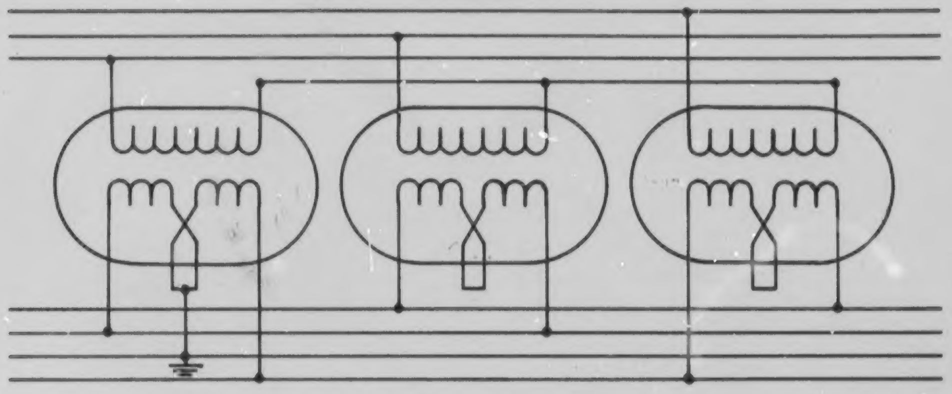


a. ______________________________

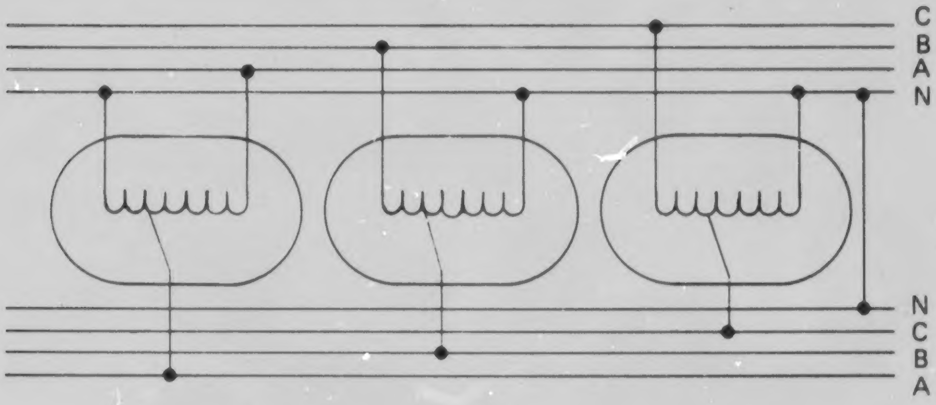


b. ______________________________

TEST

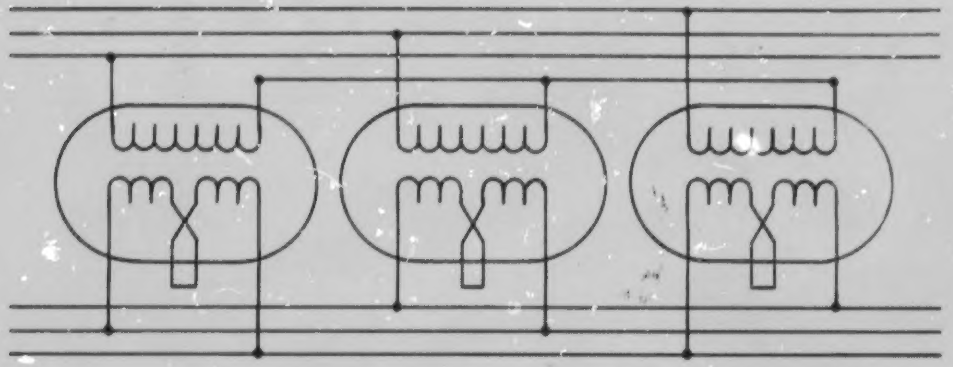


c. ______________________________



d. ______________________________

TEST



e. ______________________________

10. List four methods of identifying transformer leads for hook-up.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

11. Calculate transformer values in the following problems.

a. A transformer has a voltage input of 120 volts and a turns ratio of 1:10. What is the output voltage?

Output voltage = ______________________________ V

TEST

b. In the above circuit, the secondary current is 12 amperes. What is the primary current?

Primary current = ______________________________ A

c. A transformer circuit has an input voltage of 208 volts, a turns ratio of 1:2, and a secondary load impedance of 4 ohms. What will output power be?

Output power = ______________________________ VA

d. If the above transformer is operating at 50 percent efficiency, what is the output power?

Output power = ______________________________ VA

12. Arrange in order the steps in identifying three-phase transformer connections. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. Rearrange components in one or more sketches until the configuration is determined

_____b. Label circuit components and connection points

_____c. Resketch circuit so that connections along the same wire are all at one point, looping wires as necessary, and avoiding crossing wires as much as possible

_____d. Resketch circuit, omitting any wire that does not go from one device to another

TEST

13. Calculate the power in the three-phase circuits in the following problems.

    a. A delta connected transformer has 5 amps on each line. The voltage is 208 volts. What is the power of the circuit?

       Power = ______________________________

    b. A wye connected transformer has a voltage of 120 volts with 3 amps on each lead. What is the power of the circuit?

       Power = ______________________________

(NOTE: Test questions 14-17 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

14. Calculate transformer power, voltage, and current.

15. Find faults in transformer wiring diagrams.

16. Diagram transformer connections for three-phase power.

17. Demonstrate the ability to

    a. Check transformer polarities with a voltmeter.

    b. Examine the frequency response of a transformer.

    c. Set up transformer backfeed in a parallel circuit.

    d. Determine the configuration of a multiple-winding transformer.

    e. Check a transformer using an insulation tester.

TRANSFORMERS
UNIT IV

ANSWERS TO TEST

1. a. 4
   b. 3
   c. 7
   d. 9
   e. 1
   f. 5
   g. 8
   h. 6
   i. 2

2. a. Electromagnetic force
   b. High voltage
   c. Primary
   d. Transformer
   e. Kilovolt amperes
   f. Volts alternating current
   g. Power
   h. Center tap
   i. Current squared times resistance
   j. Number of secondary coil wraps
   k. Phase
   l. Symbol for wires not connected
   m. Symbol for ground connection
   n. Greek letter *delta*; indicates a circuit configuration
   o. Potential transformer
   p. Wye, or star; indicates a circuit configuration
   q. Symbol for wire connections
   r. Number of primary coil wraps
   s. Voltage
   t. Watt
   u. Current

ANSWERS TO TEST

v. Kilowatt

w. Secondary

x. Volt

y. Voltage in primary

z. Current in secondary

aa. Ampere

bb. Voltage in secondary

cc. Current in primary

dd. Volt amperes

ee. Volts direct current

3. a. Iron-core transformer with grounded core and center tap secondary

b. Multitap primary; multiple secondary transformer

c. One-line diagram potential transformer

d. Variable core transformer

e. One-line diagram transformer

f. Simple air-core transformer

g. Autotransformer

h. Variable auto transformer

i. Simple iron-core transformer

j. Standard power distribution transformer

k. One-line diagram current transformer

4. a. 2

b. 3

c. 4

d. 1

e. 5

f. 6

g. 7

h. 10

i. 12

j. 8

k. 11

l. 9

ANSWERS TO TEST

5. a. Conductor loss
   b. Core loss
   c. Insulation loss

6. Discussion should include
   A. Conductor loss--Reduced by using good conductors
   B. Core loss
      1. Hysteresis loss--Reduced by making core out of material suitable for operating frequency
      2. Eddy current loss--Reduced by making core in form of laminations or sheets of metal which are insulated from each other
      3. Flux loss--Reduced through core construction design and shielding
   C. Insulation loss--Reduced with good insulation material, including oil or other coolant material

7. a. High voltage, boosted by 240 volts
   b. 120/240 volts, three-wire with additional power capacity of two transformers
   c. 240 volts, two-wire
   d. 120 volts, two-wire
   e. 208 volts, two-wire from 240 volt through autotransformer
   f. 120/240 volts, three-wire

8. a. Three-wire, 240 volts, open delta
   b. Four-wire, 120/240 volts, open delta
   d. Four-wire, 277/480 volts, delta-wye
   d. Four-wire, 240/416 volts, delta-wye
   e. Three-wire, 240 volts, delta-delta
   f. Four-wire, 120/208 volts, delta-wye

ANSWERS TO TEST

9. a. Three-wire, 240 volts, open wye to open delta
   b. Four-wire, 120/208 volts, wye-wye
   c. Four-wire, 120/240 volts, wye-delta
   d. Four-wire, 240 to 208 volts, autotransformer, wye-wye
   e. Three-wire, 240 volts, wye-delta
10. a. Transformer diagram
    b. Transformer color codes
    c. Resistance checks
    d. Voltage checks
11. a. 1,200 V
    b. 120 A
    c. 43,264 VA
    d. 21,632 VA
12. a. 4
    b. 1
    c. 2
    d. 3
13. a. 1.8 VA
    b. 623.52 VA
14. Evaluated to satisfaction of instructor
15. Evaluated to satisfaction of instructor
16. Evaluated to satisfaction of instructor
17. Performance skills evaluated to satisfaction of instructor

SWITCHES AND RELAYS
UNIT V

UNIT OBJECTIVE

After completing this unit, the student should be able to test and wire functional circuits using switches and relays. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with switches and relays to their correct definitions.
2. Match abbreviations associated with switches and relays to their correct definitions.
3. Label circuit symbols of commonly used switches.
4. Label switches used in industrial electronics.
5. Match types of switches to their correct descriptions.
6. Label circuit symbols of commonly used relays.
7. Label relays used in industrial electronics.
8. Match types of relays to their correct descriptions.
9. State meter indications of switches and relays.
10. Diagram a reversing switch circuit.
11. Diagram a remotely switched relay circuit.
12. Diagram a relay-controlled, dual-lamp circuit.
13. Demonstrate the ability to
    a. Test switch terminals with an ohmmeter.
    b. Test switch terminals with a voltmeter.
    c. Test relay terminals with an ohmmeter.
    d. Test relay terminals with a voltmeter.
    e. Wire a functional, two-way switch circuit.
    f. Wire a functional relay circuit.

SWITCHES AND RELAYS
UNIT V

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Provide students with objective sheet.

  B. Provide students with information, assignment, and job sheets.

  C. Make transparencies.

  D. Discuss unit and specific objectives.

  E. Discuss information sheet.

  F. Demonstrate and discuss procedures outlined in assignment and job sheets.

  G. Collect various switches and relays to show to students.

  H. Have students test defective relays and switches with the ohmmeter.

  I. Give test.

II. Instructional materials

  A. Objective sheet

  B. Suggested activities

  C. Information sheet

  D. Transparency masters

    1. TM #1--Switches

    2. TM #2--Switches (Continued)

    3. TM #3--Switches (Continued)

    4. TM #4--Switches (Continued)

    5. TM #5--Relays

    6. TM #6--Relays (Continued)

  E. Assignment sheets

    1. Assignment Sheet #1--Diagram a Reversing Switch Circuit

    2. Assignment Sheet #2--Diagram a Remotely Switched Relay Circuit

    3. Assignment Sheet #3--Diagram a Relay-Controlled, Dual-Lamp Circuit

SUGGESTED ACTIVITIES

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1--Test Switch Terminals with an Ohmmeter
2. Job Sheet #2--Test Switch Terminals with a Voltmeter
3. Job Sheet #3--Test Relay Terminals with an Ohmmeter
4. Job Sheet #4--Test Relay Terminals with a Voltmeter
5. Job Sheet #5--Wire a Functional, Two-Way Switch Circuit
6. Job Sheet #6--Wire a Functional Relay Circuit

H. Test

I. Answers to test

III. Unit references

A. Alerich, Walter N. *Electric Motor Control.* Albany, New York: Delmar Publishers, 1975.

B. Driscoll, Edward F. *Industrial Electronics.* Chicago: American Technical Society, 1976.

SWITCHES AND RELAYS
UNIT V

INFORMATION SHEET

I. Terms and definitions

A. Break-before-make--One of a pair of contacts that interrupts one circuit before establishing another

B. Common terminal--Terminal which is switched to other terminals in sequence and is usually connected to at least one other terminal

C. Double-pole, double-throw--Six-terminal switch or relay contact arrangement that simultaneously connects one pair of terminals to either of two other pairs of terminals

D. Double-pole, single-throw--Four terminal switch or relay contact arrangement that simultaneously opens or closes two separate circuits or both sides of the same circuit

E. Gang switch--Sections of a switch which are mechanically connected and switch at the same time

F. Make-before-break--One of a pair of contacts that connects to next circuit before disconnecting from previous circuit

G. Normally closed--Connection exists between terminals when switch or relay is in "normal" position

H. Normally open--Connection does not exist when switch or relay is in "normal" position

I. Normal position--Position that switch or relay maintains with no manual, mechanical, or electromagnetic force applied

(NOTE: Switches and relays that remain in any position indefinitely have no "normal position.")

J. Overload--Load greater than that which a device is designed to handle; switch or relay that disconnects upon sensing excessive heat or current

K. Single-pole, double-throw--Three-terminal switch or relay contact arrangement that connects one terminal to either of two other terminals

L. Single-pole, single-throw--Two-terminal switch or relay contact arrangement that opens or closes one circuit

M. Thumbwheel--Rotary switch with a numerically coded switching pattern for use in digital circuitry

N. Wafer--Segment of a rotary switch

O. Three-pole, single-throw--Two-terminal switch or relay contact arrangement that simultaneously opens or closes three circuits

INFORMATION SHEET

P. Switch--A mechanical or electrical device that completes or breaks the path of current flow

Q. Relay--An electromechanical device in which contacts are opened and closed by a variation in one electrical circuit, thereby controlling other electrical circuits

II. Abbreviations associated with switches and relays

A. **BBM**--Break-before-make

B. **C**--Common

C. **DPDT**--Double-pole, double-throw

D. **DPST**--Double-pole, single-throw

E. **K**--Relay

F. **MBB**--Make-before-break

G. **NC**--Normally closed

H. **NO**--Normally open

I. **OL**--Overload

J. **S** or **Sw**--Switch

K. **SPDT**--Single-pole, double-throw

L. **SPST**--Single-pole, single-throw

M. **Tw**--Thumbwheel

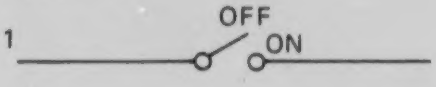
N. **3PST**--Three-pole, single-throw

III. Circuit symbols of commonly used switches (Figures 1-15)

A. Toggle switches

1. SPST

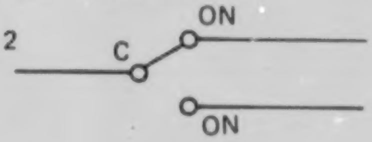
FIGURE 1



INFORMATION SHEET

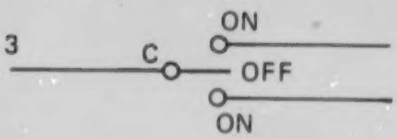
2. SPDT--2 position

FIGURE 2



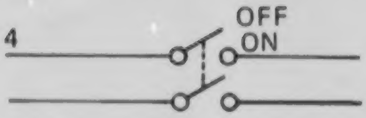
3. SPDT--3 position

FIGURE 3



4. DPST

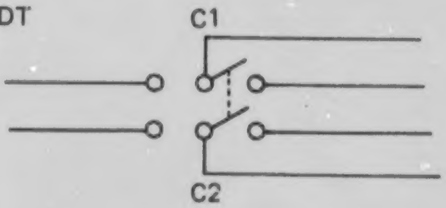
FIGURE 4



(NOTE: Dashed lines indicate that both sections work together.)

5. DPDT

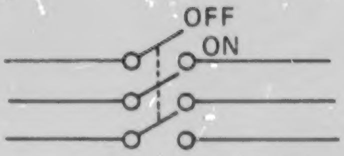
FIGURE 5



INFORMATION SHEET

6. 3PST

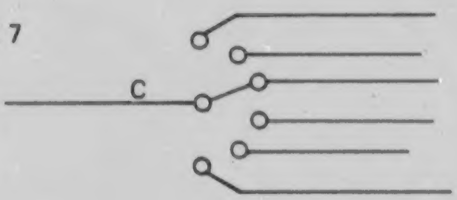
FIGURE 6



B. Rotary switches

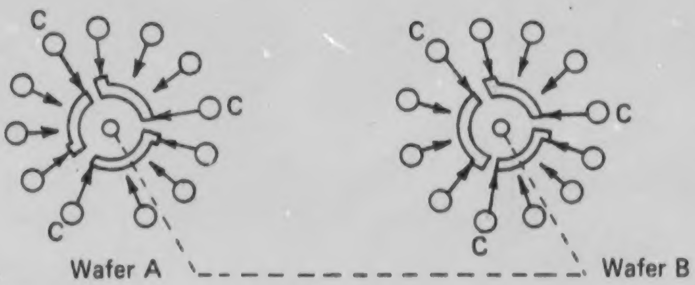
1. Simple

FIGURE 7



2. Wafer

FIGURE 8

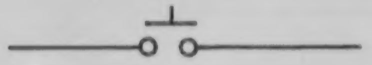

C
C
C
Wafer A
C
C
C
Wafer B

INFORMATION SHEET

C. Pushbutton switches

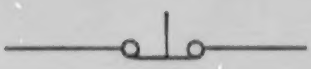
1. SPST-NO

FIGURE 9



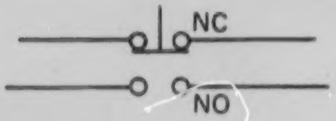
2. SPST-NC

FIGURE 10



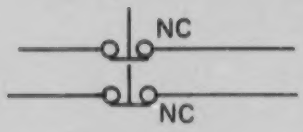
3. DPST

FIGURE 11



4. DPST-NC

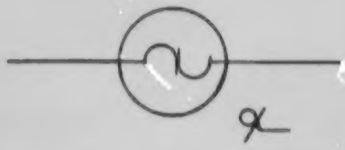
FIGURE 12



D. Special purpose switches

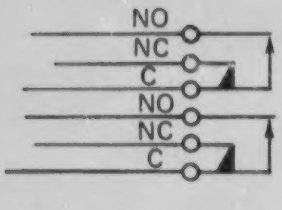
1. Thermal

FIGURE 13



2. MBB-DPDT

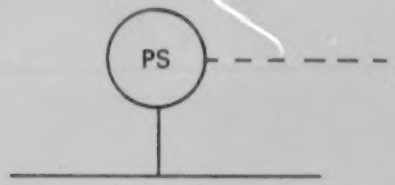
FIGURE 14


NO
NC
C
NO
NC
C

INFORMATION SHEET

3. Control switches in flow diagrams

FIGURE 15



(NOTE: The pressure switch in Figure 15 is a kind of control switch. Solid lines represent piping, and dashed lines represent electrical connection.)

IV. Switches used in industrial electronics (Transparencies #1, #2, #3, and #4)

   A. Toggle

   B. Rotary

   C. Pushbutton

   D. Knife

   E. Mercury

   F. Thumbwheel

   G. Bimetal strip (thermal)

   H. Limit

   I. Miniature snap action

V. Types of switches

   A. Toggle--Switches only a few circuits between only two or three connections

      EXAMPLE: Ordinary household wall switch

   B. Rotary--Selects one of several connections; can switch many circuits

      EXAMPLE: Television channel selector

   C. Pushbutton--Switches only a few circuits by depressing a button

      EXAMPLE: Doorbell button

INFORMATION SHEET

D. Knife--Open contacts allow visual verification of switch position

EXAMPLE: Air conditioner disconnect

E. Mercury--Automatically switches a few circuits by tilting glass bulb

EXAMPLES: Heating and air conditioning wall thermostat

F. Thumbwheel--Switches terminals in a numerical pattern that can be decoded by special circuitry known as *digital circuitry*

EXAMPLE: Selector on computer control panel

G. Bimetal strip (thermal)--Switches at a certain temperature due to expansion differences of metals

EXAMPLE: Refrigerator temperature control

H. Limit--Switches by motion of lever or cam; used on large mechanical devices

EXAMPLES: Motor shut-off switch for electrically operated valves, garage doors

I. Miniature snap action--Switches as a result of very small mechanical movement; small power applications in electromechanical devices

EXAMPLE: Switches used in teletype units

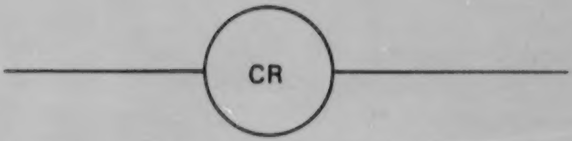
VI. Circuit symbols of commonly used relays (Figures 16-20)

A. Relay circuit symbols used in control diagrams

1. Coils

a. Shunt

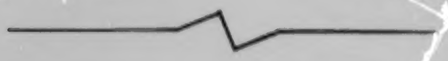
FIGURE 16



INFORMATION SHEET

b. Series

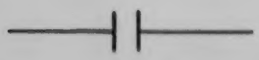
FIGURE 17



2. Contacts

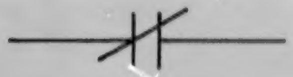
a. Normally open

FIGURE 18



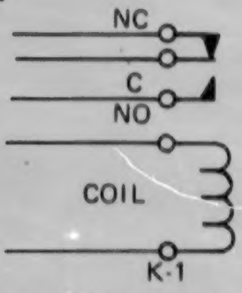
b. Normally closed

FIGURE 19



B. Relay circuit symbol used in electronic schematics

FIGURE 20



VII. Relays used in industrial electronics (Transparencies #5 and #6)

A. Mercury wetted

B. Reed

INFORMATION SHEET

- C. Solid-state
- D. Octal base plug-in
- E. Conventional

VIII. Relay descriptions

- A. General
    - 1. Used for remote switching
    - 2. Capable of automatic switching by electrical sensors
    - 3. Capable of absolute contact opening and closing without the leakage current
- B. Mercury wetted
    - 1. Capable of minimal and nonvarying contact resistance
    - 2. Used for sensitive electronic devices

      EXAMPLE: Relays connecting temperature sensors to a computer system
- C. Reed
    - 1. Used in small power applications
    - 2. Used often on printed circuit boards

      EXAMPLE: Relay operating counting device driven by printed circuit board
- D. Solid-state
    - 1. Used with transistor devices
    - 2. Capable of high speed, repetitious switching
    - 3. Used often in communications

      EXAMPLE: Modern telephone exchange systems
- E. Conventional electromechanical
    - 1. Used in large power applications
    - 2. Simple and reliable operation

      EXAMPLE: Conventional automobile regulator

INFORMATION SHEET

IX. Meter indications of switches and relays

A. Using an ohmmeter

(NOTE: The switch or relay must be disconnected from the circuit.)

1. Closed contacts--Measure zero ohms
2. Open contacts--Measure infinite resistance
3. Relay coils or defective contacts--Measure some resistance value
4. Common terminals--Measure zero ohms to at least one other terminal in all switch positions or relay states
5. NO terminals--Measure infinite ohms to common terminal and any other terminal when switch or relay is in "normal" position
6. NC terminals--Measure zero ohms to the common terminal or other terminal when switch or relay is in "normal" position
7. Relay coil terminals
   a. Vary in resistance but generally measure from a few tenths of an ohm to several ohms
   b. Ordinarily measure infinite resistance to all other terminals as well as to frame or case
8. Frame or case--Ordinarily measure infinite resistance to any terminal

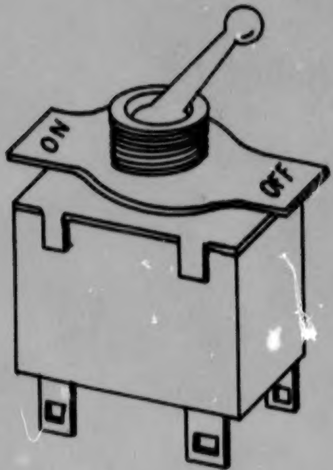
B. Using a voltmeter

(NOTE: The procedure assumes that the switch or relay is in a live circuit with voltage applied.)

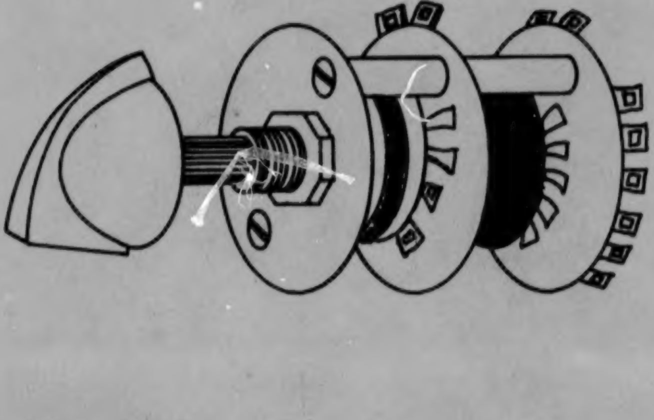
1. Closed contacts--Measure zero volts
2. Open contacts--Measure level of voltage applied
3. Common terminals--Measure zero volts to one other terminal in any switch or relay positon
4. Coil terminals--Measure rated voltage when relay is activated
5. Defective contacts--Measure some unpredictable voltage

Switches

Toggle

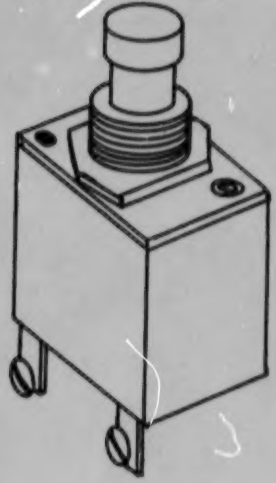


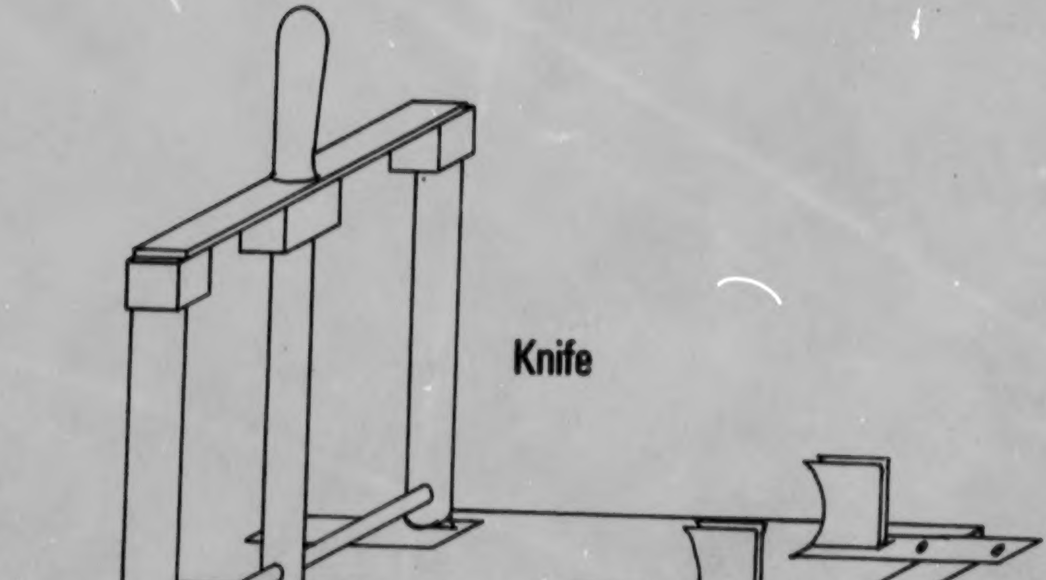
Rotary With Two Wafers



Switches
(Continued)

Pushbutton



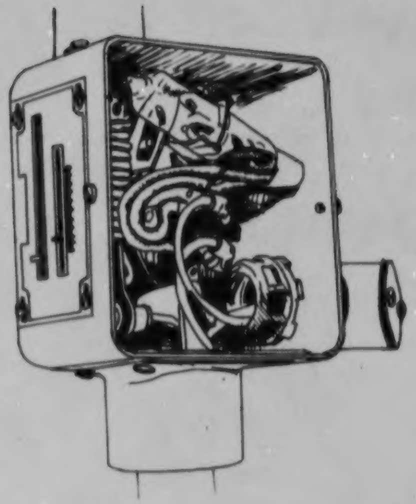


Knife

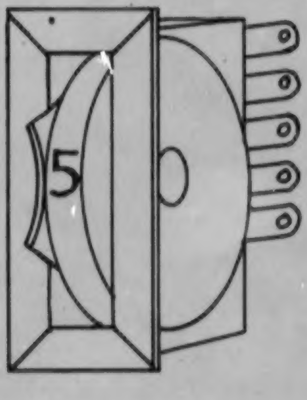
800

Switches
(Continued)

Mercury



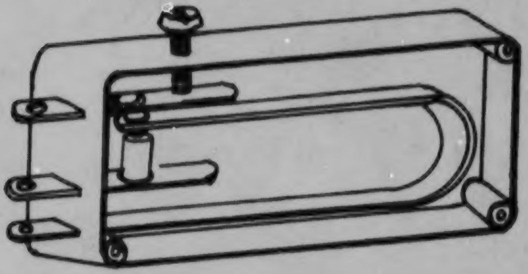
Thumbwheel



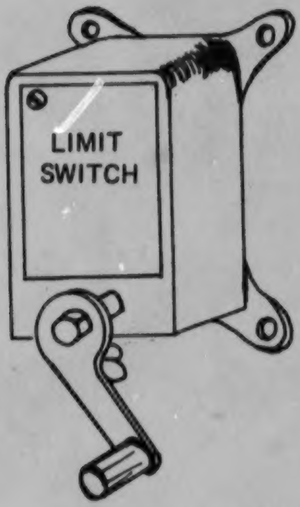
801

Switches
(Continued)

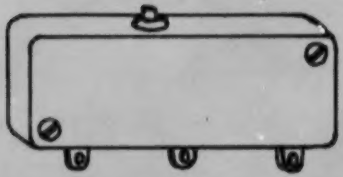
Bi-Metal Strip (Thermal)



Limit


LIMIT
SWITCH

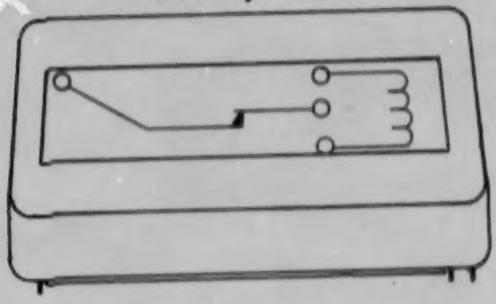
Miniature Snap Action



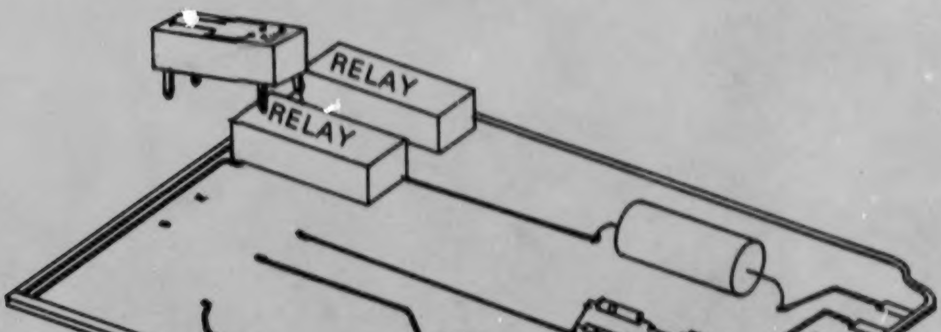
802

Relays

Mercury-Wetted

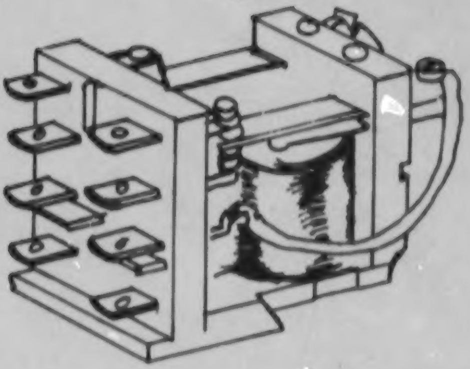


Reed Relay (Mounted on a Printed Circuit Board)

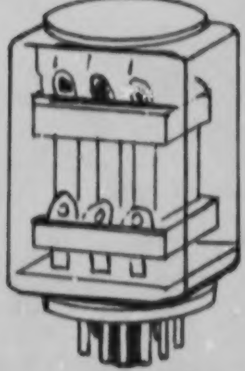

RELAY
RELAY

Relays
(Continued)

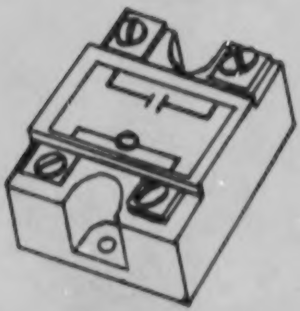
Conventional



Octal Base Plug-In



Solid-State



SWITCHES AND RELAYS
UNIT V

ASSIGNMENT SHEET #1--DIAGRAM A REVERSING SWITCH CIRCUIT

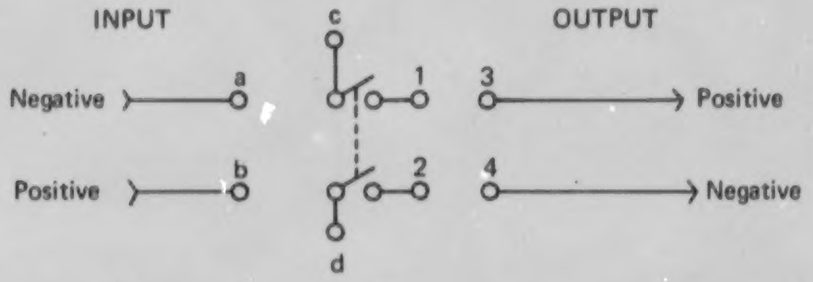
NAME ______________________________ SCORE ______________

Unless a circuit is simple, the first step toward wiring is to make a diagram, sketch, or schematic. Complete the following wiring diagrams (Figures 21-23) according to the accompanying instructions.

A. Connect the lettered terminals on the left to each other, and connect the numbered terminals on the right to each other so that the output will be switched off and on as indicated

(NOTE: Input is generally connected to the center or movable arm contacts.)

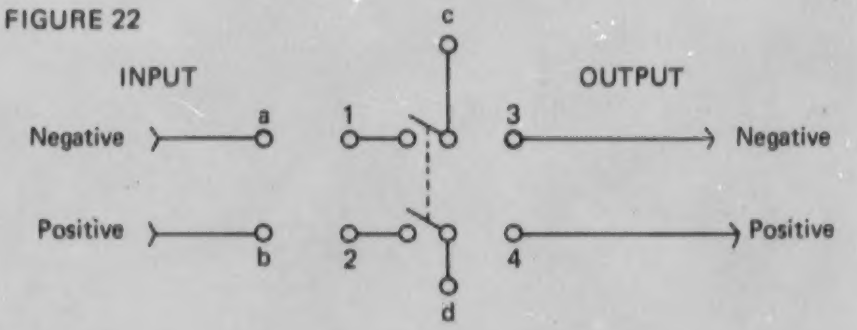
FIGURE 21


INPUT
c
OUTPUT
Negative
a
1
3
Positive
Positive
b
2
4
Negative
d

B. Again, connect the lettered terminals, and then connect the numbered terminals so that the output is switched on and off as indicated

(NOTE: Observe the change in the output wires.)

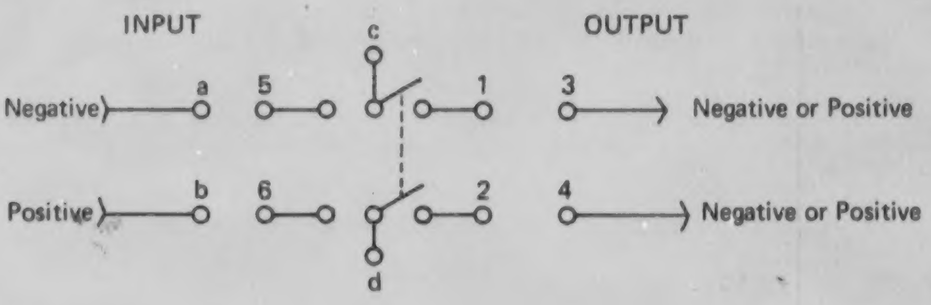
FIGURE 22


c
INPUT
OUTPUT
Negative
a
1
3
Negative
Positive
b
2
4
Positive
d

ASSIGNMENT SHEET #1

C. Now combine the two circuits into a single circuit that can switch the output from positive-negative to negative-positive. Again, connect numbered terminals to numbered terminals and lettered terminals to lettered terminals

FIGURE 23


INPUT
OUTPUT
c
a
5
1
3
Negative
Negative or Positive
b
6
2
4
Positive
Negative or Positive
d

SWITCHES AND RELAYS
UNIT V

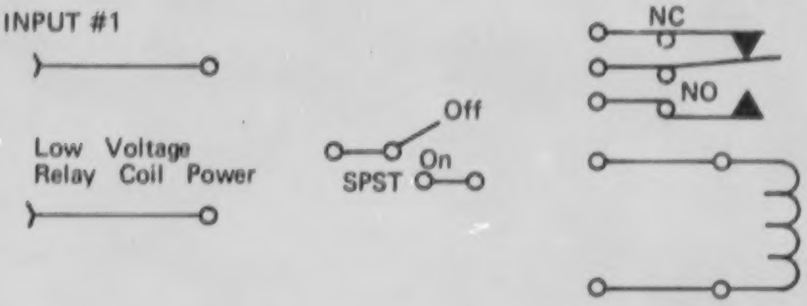
ASSIGNMENT SHEET #2–DIAGRAM A REMOTELY SWITCHED RELAY CIRCUIT

NAME ______________________________ SCORE ______________

Relay circuits often are much more complicated than switch circuits. It is often necessary to sketch a circuit before it can be wired. Complete the following wiring diagrams (Figures 24 and 25) according to the accompanying instructions.

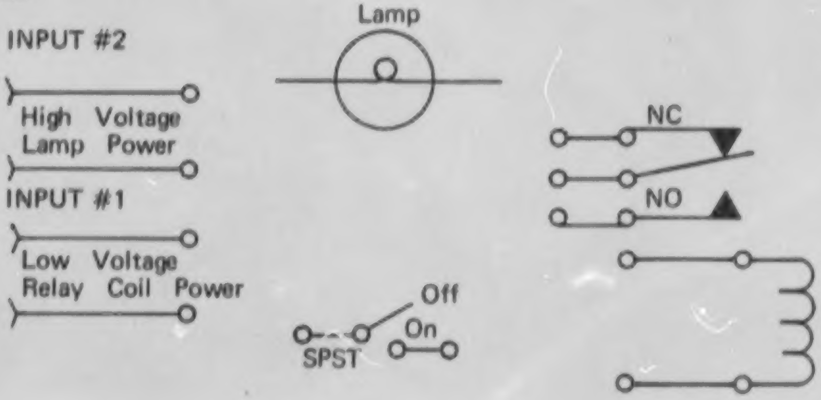
A. Without considering the relay contacts, connect the relay coil to the power so that the switch turns the power to the coil on and off

FIGURE 24


INPUT #1
Low Voltage Relay Coil Power
Off
On
SPST
NC
NO

B. Without considering the coil circuit, connect the lamp to the high voltage source through the normally closed contacts in the circuit below

FIGURE 25


Lamp
INPUT #2
High Voltage Lamp Power
INPUT #1
Low Voltage Relay Coil Power
Off
On
SPST
NC
NO

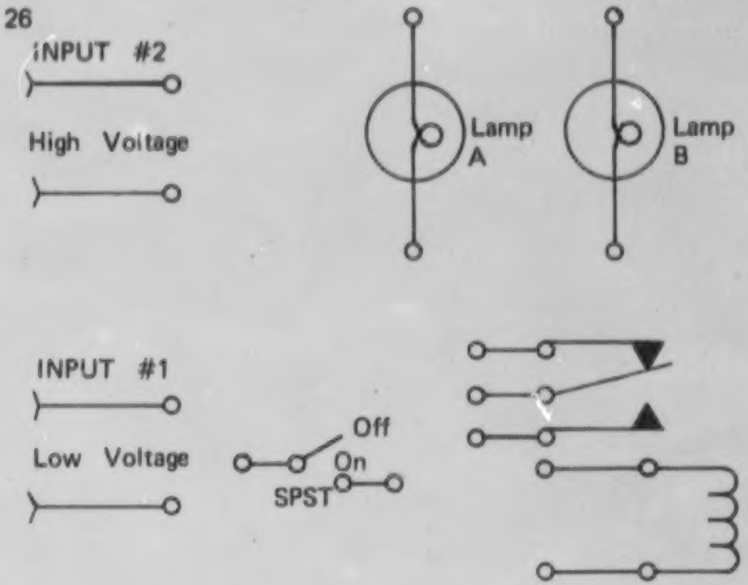
SWITCHES AND RELAYS
UNIT V

ASSIGNMENT SHEET #3--DIAGRAM A RELAY-CONTROLLED, DUAL-LAMP CIRCUIT

NAME ______________________________ SCORE ______________

Assuming that only the NC terminal of the relay is used, connect one high voltage input to the common relay contact and connect the other terminals to the two lamps in the circuit in Figure 26. Make the connections so that lamp A is normally on, and lamp B is normally off.

FIGURE 26

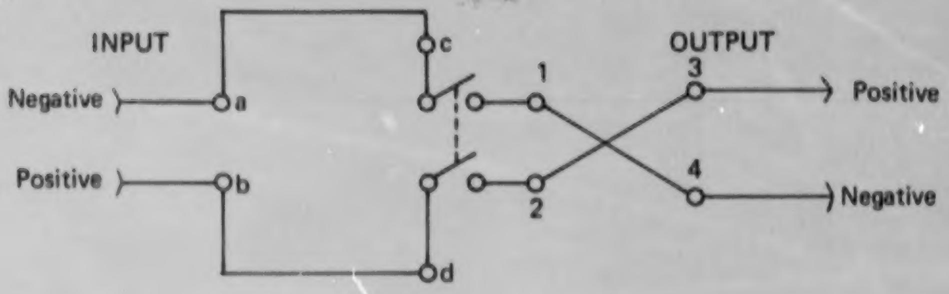

INPUT #2
High Voltage
Lamp A
Lamp B
INPUT #1
Low Voltage
Off
On
SPST

SWITCHES AND RELAYS
UNIT V

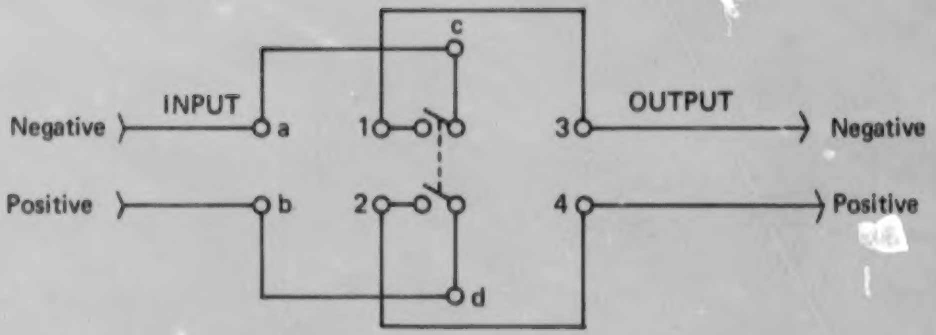
ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A.

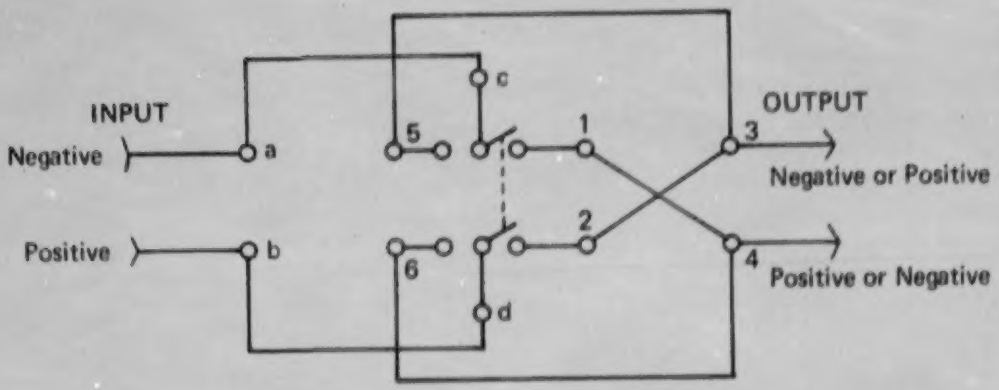

INPUT
Negative
Positive
a
b
c
d
1
2
OUTPUT
3
4
Positive
Negative

B.


INPUT
Negative
Positive
a
b
c
d
1
2
3
4
OUTPUT
Negative
Positive

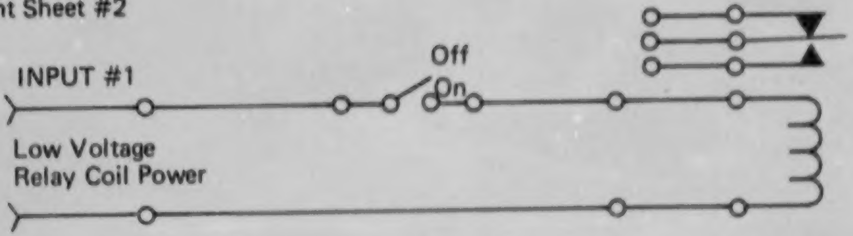
ANSWERS TO ASSIGNMENT SHEETS

C.

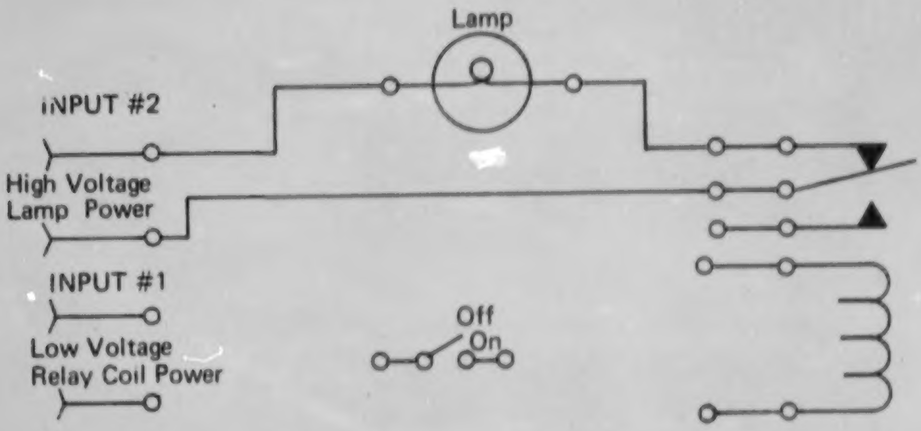

INPUT
Negative
Positive
a
b
c
d
5
6
1
2
3
4
OUTPUT
Negative or Positive
Positive or Negative

Assignment Sheet #2

A.

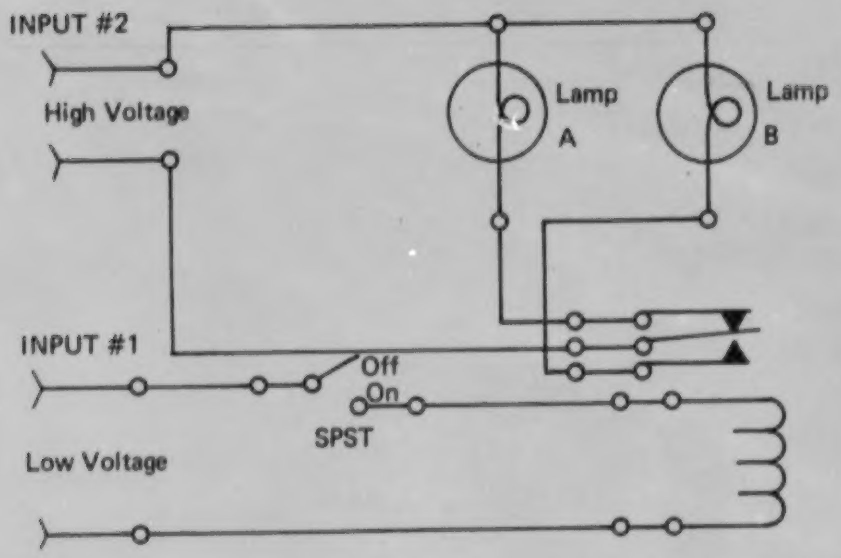

INPUT #1
Off
On
Low Voltage
Relay Coil Power

B.


Lamp
INPUT #2
High Voltage
Lamp Power
INPUT #1
Off
On
Low Voltage
Relay Coil Power

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #3


INPUT #2
High Voltage
Lamp
A
Lamp
B
INPUT #1
Off
On
SPST
Low Voltage

SWITCHES AND RELAYS
UNIT V

JOB SHEET #1--TEST SWITCH TERMINALS WITH AN OHMMETER

I. Equipment and materials

   A. Multimeter

   B. Various switches--Types determined by instructor

II. Procedure

   A. Set multimeter controls for resistance measurement

   B. Measure across the various switch terminals while changing switch positions until the switch contacts can be identified and the contacts are determined to be satisfactory or defective

   (NOTE: If assistance is needed, see your instructor.)

   C. In the space below, draw the correct circuit symbol for each switch

   D. Label each circuit symbol with its proper switch type

   EXAMPLES: SPST, DPDT, etc.

   (NOTE: Check your results with the instructor.)

   E. Put equipment and materials away

SWITCHES AND RELAYS
UNIT V

JOB SHEET #2--TEST SWITCH TERMINALS WITH A VOLTMETER

I. Equipment and materials

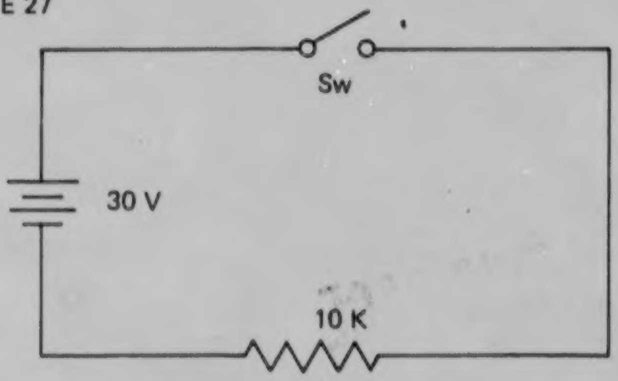
- A. Multimeter
- B. Switch--SPST
- C. Resistor--10 Kohm
- D. Power supply

II. Procedure

- A. Construct circuit shown in Figure 27

  (NOTE: Be sure power supply is turned off and voltage control is fully counterclockwise.)

FIGURE 27



- B. Turn on power supply
- C. Adjust output to voltage specified by instructor
- D. Measure voltages across the switch terminals while changing switch positions
- E. Record your findings in the space below

  ____

  ____

  (NOTE: Check your results with the instructor.)

- F. Put equipment and materials away

SWITCHES AND RELAYS
UNIT V

JOB SHEET #3--TEST RELAY TERMINALS WITH AN OHMMETER

I. Equipment and materials

A. Multimeter

B. Relays--Types determined by instructor

(NOTE: For relays that cannot be manually operated, a preconstructed control circuit will be required with an on/off switch and power supply to energize the relay coil, leaving all other terminals unconnected.)

II. Procedure

A. Set multimeter controls for resistance measurement

B. Measure across the various relay terminals while operating the relay until the terminals can be identified and the contacts are determined to be satisfactory or defective

(NOTE: If assistance is needed, see your instructor.)

C. Draw the correct circuit symbol for each relay

(NOTE: Check your results with the instructor.)

D. Put equipment and materials away

SWITCHES AND RELAYS
UNIT V

JOB SHEET #4--TEST RELAY TERMINALS WITH A VOLTMETER

I. Equipment and materials

A. Multimeter

B. Relay--DPDT

C. Switch--SPST

D. Power supply

E. Resistor--10 Kohm

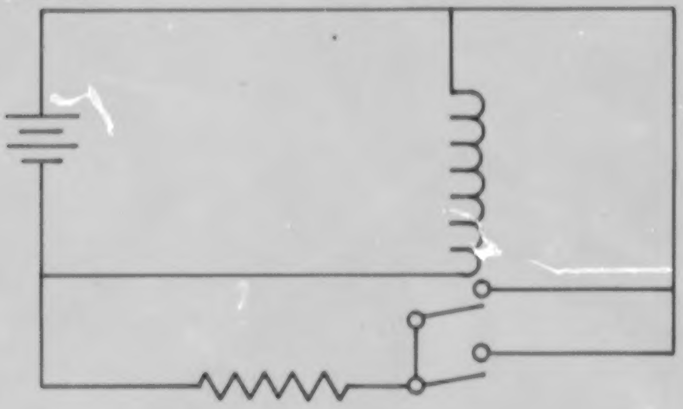
F. Test leads

II. Procedure

A. Construct circuit shown in Figure 28

(NOTE: Be sure power supply is turned off and voltage adjust is fully counterclockwise.)

FIGURE 28



B. Turn on power supply

C. Adjust power supply voltage to value specified by instructor

D. Measure voltages across the relay terminals while operating the relay until the terminals can be identified and the contacts are determined to be satisfactory or defective

(NOTE: If assistance is needed, see your instructor.)

JOB SHEET #4

E. Explain how energizing the relay affected the voltage measurements of the relay contacts

____

____

____

____

(NOTE: Check your results with the instructor.)

F. Put equipment and materials away

SWITCHES AND RELAYS
UNIT V

JOB SHEET #5--WIRE A FUNCTIONAL, TWO-WAY SWITCH CIRCUIT

I. Equipment and materials

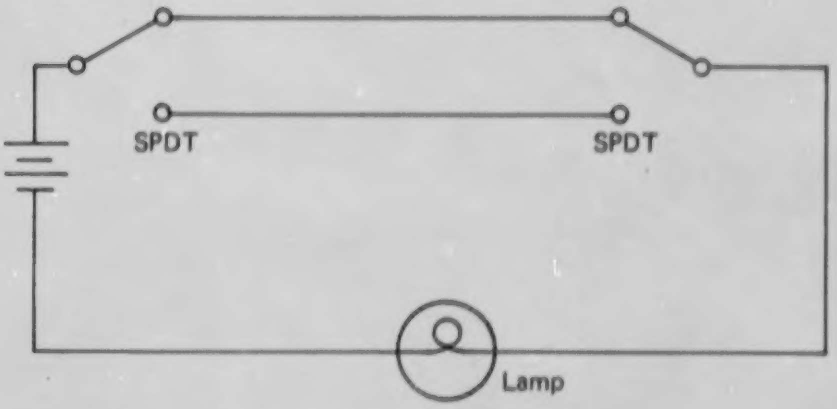
- A. Switches--2 SPDT
- B. Power supply
- C. Low voltage lamp
- D. Lamp socket
- E. Test leads

II. Procedure

A. Construct the circuit shown in Figure 29

(NOTE: Be sure power supply is turned off and voltage adjust is fully counterclockwise.)

FIGURE 29



(NOTE: Have the instructor inspect the circuit.)

B. Turn on power supply

C. Adjust output voltage level to match lamp requirement

D. Test the circuit for proper operation

(NOTE: Check your results with the instructor.)

E. Put equipment and materials away

SWITCHES AND RELAYS
UNIT V

JOB SHEET #6--WIRE A FUNCTIONAL RELAY CIRCUIT

I. Equipment and materials

- A. Low voltage relay
- B. SPST switch
- C. Power supply
- D. Lamps--2, 120 VAC
- E. Lamp sockets--2
- F. Test leads

II. Procedure

- A. Wire the circuit diagramed in Figure 26, Assignment Sheet #3, but do not connect to the 120 VAC source
- B. With the power supply disconnected, adjust the power supply output to match the specified relay voltage

  (NOTE: Have the instructor inspect the circuit.)
- C. Connect the relay coil to the low voltage power supply, and test the circuit without the 120 VAC connected
- D. Connect the circuit to 120 VAC, and test for proper operation

  (NOTE: Check your results with the instructor.)
- E. Put equipment and materials away

SWITCHES AND RELAYS
UNIT V

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with switches and relays to the correct definitions. Write the correct numbers in the blanks provided.

______a. Two-terminal switch or relay contact arrangement that simultaneously opens or closes three circuits

______b. Segment of a rotary switch

______c. Rotary switch with a numerically coded switching pattern for use in digital circuitry

______d. Three-terminal switch or relay contact arrangement that connects one terminal to either of two other terminals

______e. Two-terminal switch or relay contact arrangement that opens or closes one circuit

______f. Load greater than that which a device is designed to handle; switch or relay that disconnects upon sensing excessive heat or current

______g. Position that switch or relay maintains with no manual, mechanical, or electromagnetic force applied

______h. Connection does not exist when switch or relay is in "normal" position

______i. Connection exists between terminals when switch or relay is in "normal" position

______j. One of a pair of contacts that connects to next circuit before disconnecting from previous circuit

______k. Sections of a switch which are mechanically connected and switch at the same time

______l. Four-terminal switch or relay contact arrangement that simultaneously opens or closes two separate circuits or both sides of the same circuit

1. Normally open
2. Thumbwheel
3. Gang switch
4. Overload
5. Make-before-break
6. Single-pole, double-throw
7. Wafer
8. Three-pole, single-throw
9. Single-pole, single-throw
10. Normally closed
11. Normal position
12. Double-pole, single-throw

TEST

______m. Six-terminal switch or relay contact arrangement that simultaneously connects one pair of terminals to either of two other pairs of terminals

______n. Terminal which is switched to other terminals in sequence and is usually connected to at least one other terminal

______o. One of a pair of contacts that interrupts one circuit before establishing another

______p. An electromechanical device in which contacts are opened and closed by a variation in one electrical circuit, thereby controlling other electrical circuits

______q. A mechanical or electrical device that completes or breaks the path of current flow

13. Break-before-make
14. Common terminal
15. Double-pole, double-throw
16. Switch
17. Relay

2. Match abbreviations associated with switches and relays to their correct definitions. Write the correct numbers in the blanks.

______a. Three-pole, single-throw

______b. Thumbwheel

______c. Single-pole, single-throw

______d. Single-pole, double-throw

______e. Switch

______f. Overload

______g. Normally open

______h. Normally closed

______i. Make-before-break

______j. Relay

______k. Double-pole, single-throw

______l. Double-pole, double-throw

______m. Common

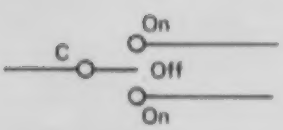
______n. Break-before-make

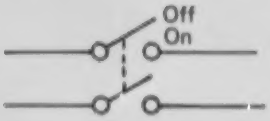
1. SPDT
2. NO
3. Tw
4. K
5. OL
6. C
7. SPST
8. BBM
9. MBB
10. 3PST
11. DPDT
12. NC
13. DPST
14. S or Sw

TEST

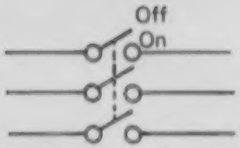
3. Label circuit symbols of commonly used switches.

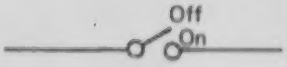
   a. Toggle switches



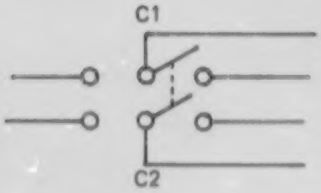


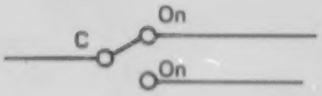
1) ______________________ 2) ______________________





3) ______________________ 4) ______________________

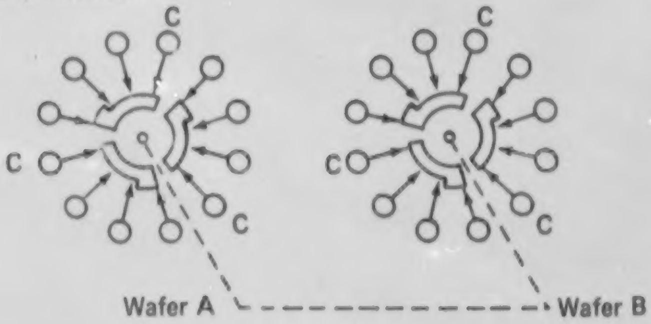




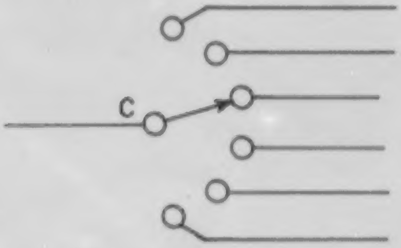
5) ______________________ 6) ______________________

TEST

b. Rotary switches

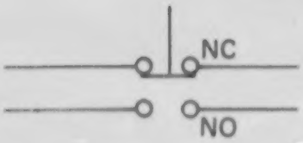

C
C
C
C
C
C
Wafer A
Wafer B

1) ______________________________

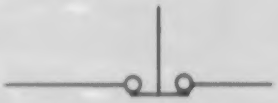


2) ______________________________

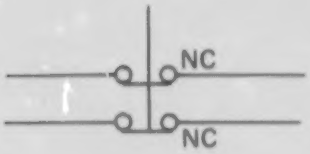
c. Pushbutton switches



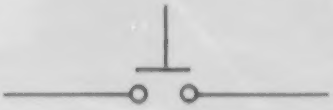
1) ______________



2) ______________



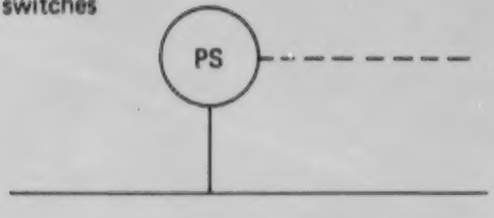
3) ______________



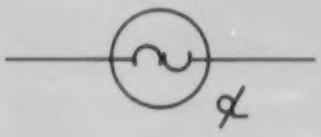
4) ______________

TEST

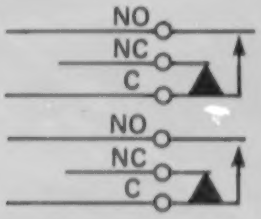
d. Special purpose switches



1) ______________________________

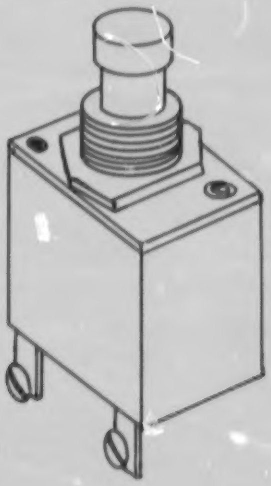


2) ______________________________


NO
NC
C
NO
NC
C

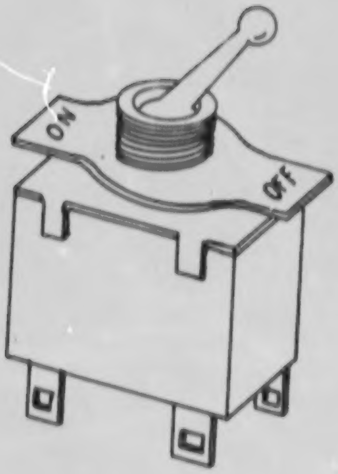
3) ______________________________

4. Label switches used in industrial electronics.

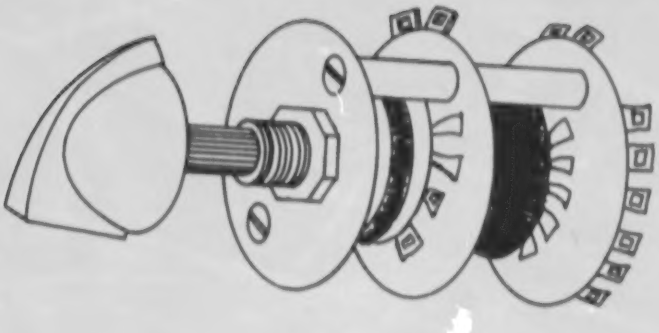


a. ______________________________

TEST

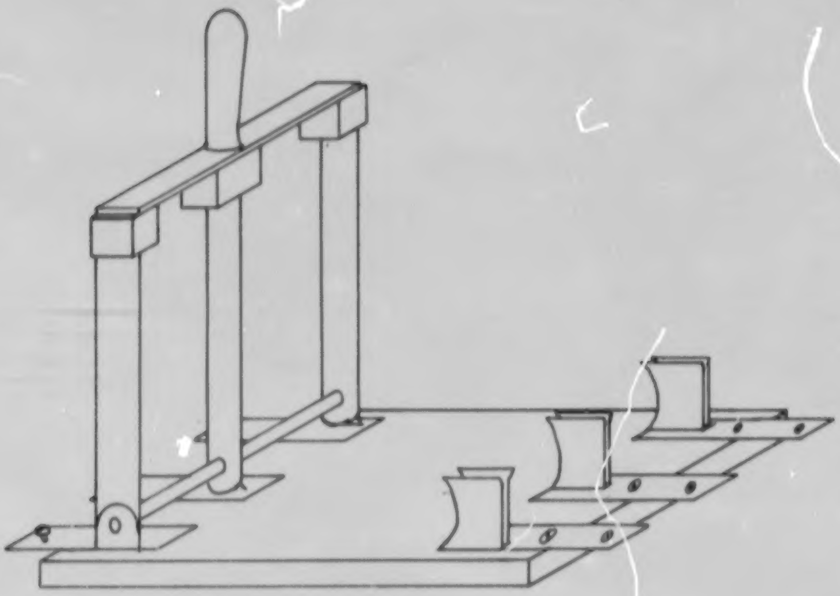


b. ______________________________

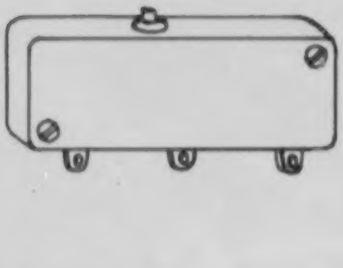


c. ______________________________

TEST

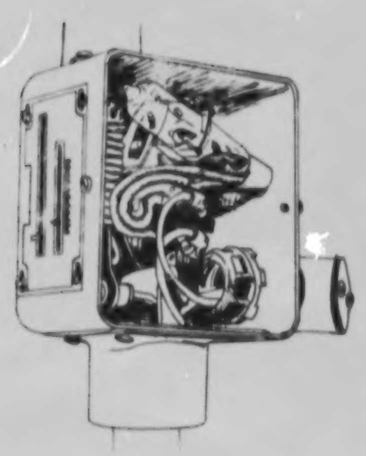


d. ____________________

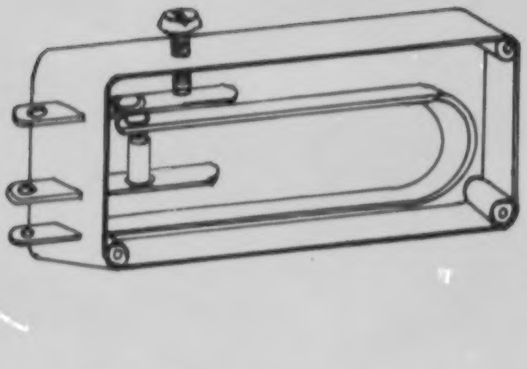


e. ____________________

TEST

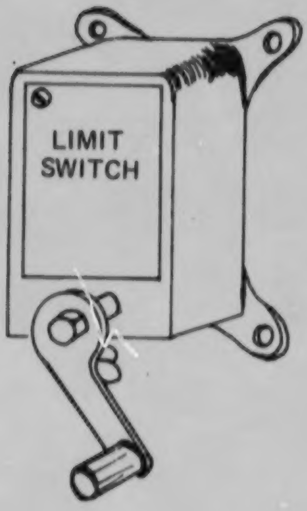


f. ____

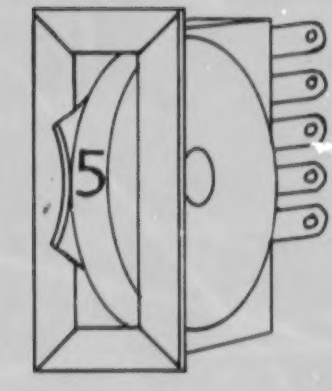


g. ____

TEST


LIMIT
SWITCH

h. ______________________________



i. ______________________________

TEST

5. Match types of switches to their correct descriptions. Write the correct numbers in the blanks.

______a. Switches as a result of very small mechanical movement; small power applications in electromechanical devices

______b. Switches by motion of lever or cam; used on large mechanical devices

______c. Switches at a certain temperature due to expansion differences of metals

______d. Switches terminals in a numerical pattern that can be decoded by special circuitry known as *digital circuitry*

______e. Automatically switches a few circuits by tilting glass bulb

______f. Open contacts allow visual verification of switch position

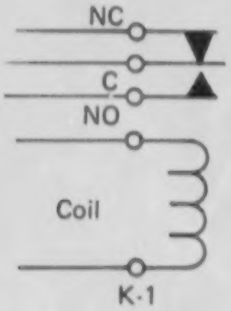
______g. Switches only a few circuits by depressing a button

______h. Selects one of several connections; can switch many circuits

______i. Switches only a few circuits between only two or three connections

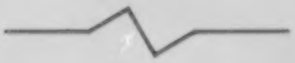
1. Bimetal strip (thermal)
2. Toggle
3. Knife
4. Miniature snap action
5. Pushbutton
6. Thumbwheel
7. Mercury
8. Rotary
9. Limit

6. Label circuit symbols of commonly used relays.

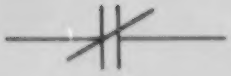


a. ____

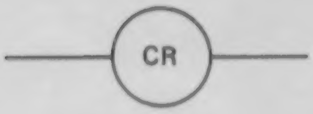
TEST



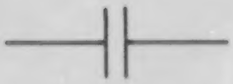
b. ______________________



c. ______________________

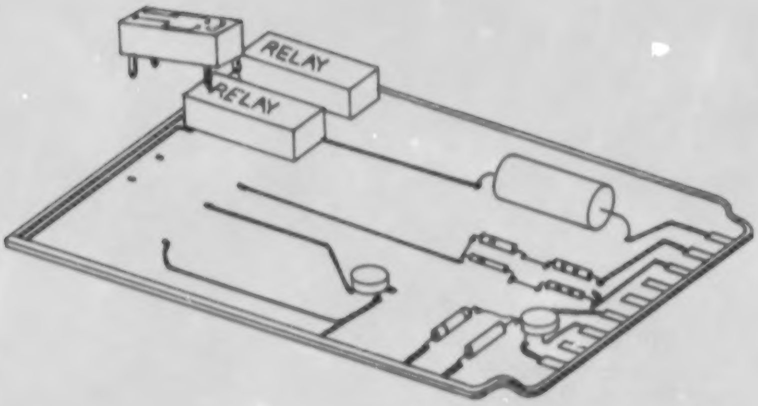


d. ______________________



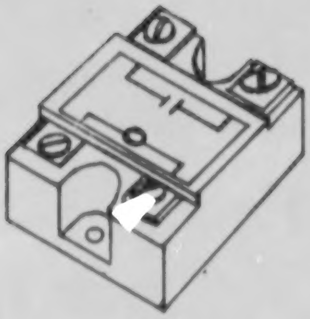
e. ______________________

7. Label relays used in industrial electronics.

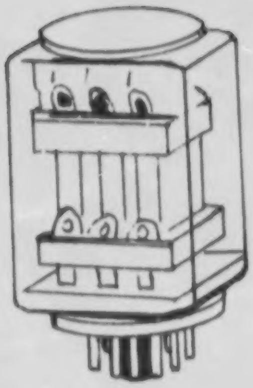

RELAY
RELAY

a. ______________________

TEST

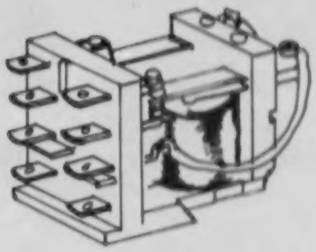


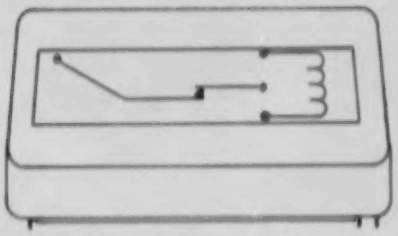
b. ______________________________



c. ______________________________

TEST





d. ______________________________ e. ______________________________

8. Match types of relays to their correct descriptions. Write the correct numbers in the blanks. Numbers may be used more than once.

_____a. Used with transistor devices

_____b. Used in small power applications

_____c. Capable of minimal and nonvarying contact resistance

_____d. Used for remote switching

_____e. Used often on printed circuit boards

_____f. Simple and reliable operation

_____g. Used in large power applications

_____h. Capable of automatic switching by electrical sensors

_____i. Used often in communications

_____j. Capable of absolute contact opening and closing without the leakage current

_____k. Capable of high speed, repetitious switching

_____l. Used for sensitive electronic devices

1. General
2. Mercury wetted
3. Reed
4. Solid-state
5. Conventional electromechanical

TEST

9. State meter indications of switches and relays.

   a. Using an ohmeter

      1) Closed contacts-- ____________________

      2) Open contacts-- ____________________

      3) Relay coils or defective contacts-- ____________________

      4) Common terminals-- ____________________

      5) NO terminals-- ____________________

      6) NC terminals-- ____________________

      7) Relay coil terminals--

         a. ____________________

         b. ____________________

      8) Frame or case-- ____________________

   b. Using a voltmeter

      1) Closed contacts-- ____________________

      2) Open contacts-- ____________________

TEST

3) Common terminals-- ______________________________

____

4) Coil terminals-- ______________________________

____

5) Defective contacts-- ______________________________

____

(NOTE: Test questions 10-13 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

10. Diagram a reversing switch circuit.

11. Diagram a remotely switched relay circuit.

12. Diagram a relay-controlled, dual-lamp circuit.

13. Demonstrate the ability to

    a. Test switch terminals with an ohmmeter.

    b. Test switch terminals with a voltmeter.

    c. Test relay terminals with an ohmmeter.

    d. Test relay terminals with a voltmeter.

    e. Wire a functional, two-way switch circuit.

    f. Wire a functional relay circuit.

SWITCHES AND RELAYS
UNIT V

ANSWERS TO TEST

1. a. 8
   b. 7
   c. 2
   d. 6
   e. 9
   f. 4
   g. 11
   h. 1
   i. 10
   j. 5
   k. 3
   l. 12
   m. 15
   n. 14
   o. 13
   p. 17
   q. 16

2. a. 10
   b. 3
   c. 7
   d. 1
   e. 14
   f. 5
   g. 2
   h. 12
   i. 9
   j. 4
   k. 13
   l. 11
   m. 6
   n. 8

3. a. Toggle switches
      1) SPDT-3 position
      2) DPST
      3) 3PST
      4) SPST
      5) DPDT
      6) SPDT-2 position
   b. Rotary switches
      1) Wafer
      2) Simple

ANSWERS TO TEST

c. Pushbutton switches

    1) DPST

    2) SPST-NC

    3) DPST-NC

    4) SPST-NO

d. Special purpose switches

    1) Control switches in flow diagrams

    2) Thermal

    3) MBB-DPDT

4. a. Pushbutton

    b. Toggle

    c. Rotary

    d. Knife

    e. Miniature snap action

    f. Mercury

    g. Bimetal strip (thermal)

    h. Limit

    i. Thumbwheel

5. a. 4

    b. 9

    c. 1

    d. 6

    e. 7

    f. 3

    g. 5

    h. 8

    i. 2

6. a. Relay circuit symbol used in electronic schematics

    b. Series (Coil)

    c. Normally closed (Contact)

    d. Shunt (Coil)

    e. Normally open (Contact)

7. a. Reed

    b. Solid-state

    c. Octal base plug-in

    d. Conventional

    e. Mercury wetted

ANSWERS TO TEST

8.

a.	4	g.	5
b.	3	h.	1
c.	2	i.	4
d.	1	j.	1
e.	3	k.	4
f.	5	l.	2

9. a. Using an ohmeter
    1) Measure zero ohms
    2) Measure infinite resistance
    3) Measure some resistance value
    4) Measure zero ohms to at least one other terminal in all switch positions or relay states
    5) Measure infinite ohms to common terminal and any other terminal when switch or relay is in "normal" position
    6) Measure zero ohms to the common terminal or other terminal when switch or relay is in "normal" position
    7) a) Vary in resistance but generally measure from a few tenths of an ohm to several ohms
        b) Ordinarily measure infinite resistance to all other terminals as well as to the frame or case
    8) Ordinarily measure infinite resistance to any terminal

    b. Using a voltmeter
    1) Measure zero volts
    2) Measure level of voltage applied
    3) Measure zero volts to one other terminal in any switch or relay position
    4) Measure rated voltage when relay is activated
    5) Measure some unpredictable voltage

10. Evaluated to satisfaction of instructor

11. Evaluated to satisfaction of instructor

12. Evaluated to satisfaction of instructor

13. Performance skills evaluated to satisfaction of instructor

VACUUM TUBES
UNIT VI

UNIT OBJECTIVE

After completing this unit, the student should be able to identify vacuum tubes, determine their correct pin numbers, and test vacuum tubes through the use of a tube tester or a multimeter. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with vacuum tubes to their correct definitions.
2. Match abbreviations and symbols associated with vacuum tubes to their correct definitions.
3. Match electron tube element symbols to their correct names.
4. Label vacuum tube circuit symbols.
5. Label electronic component circuit symbols.
6. List elements in a pentode vacuum tube.
7. List disadvantages of vacuum tubes compared to solid-state devices.
8. Match vacuum tube primary elements to their correct purposes.
9. Select from a list vacuum tube general biasing requirements.
10. Determine parameters of vacuum tubes.
11. Determine vacuum tube plate resistance.
12. Draw a load line on a plate dynamic characteristic curve.
13. Determine the operating point of a simple vacuum tube.
14. Determine the output voltage variation of a vacuum tube circuit.
15. Label types of vacuum tubes.
16. State the mathematical formulas and conditions of principal vacuum tube parameters.
17. State the mathematical formula for finding the relationship between vacuum tube parameters.

OBJECTIVE SHEET

18. Label vacuum tube pins.
19. Describe the vacuum tube identification type-code.
20. List common causes of vacuum tube failure.
21. Determine the operating conditions of a vacuum tube circuit.
22. Demonstrate the ability to
    a. Test a vacuum tube using a tube tester.
    b. Check a vacuum tube with an ohmmeter.

VACUUM TUBES
UNIT VI

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Set up a vacuum tube curve tracer, if available, and show characteristic curves; otherwise, show examples of tube performance data and characteristic curves from a manufacturer's reference book.

   H. Set up a simple cathode follower amplifier to show amplification and inversion using an oscilloscope.

   I. Collect old tubes for Job Sheet #2. Use a DC power supply to intentionally burn out some filaments prior to having the students test them. Number the tubes and note which ones had defective filaments.

   J. Give test.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency masters

      1. TM #1--Elements of a Vacuum Tube Pentode (Schematic)

      2. TM #2--Elements of a Vacuum Tube Pentode (Diagram)

      3. TM #3--Characteristic Curve 6SJ7

      4. TM #4--Amplifier Circuit

      5. TM #5--Characteristic Curve 6J5

      6. TM #6--Characteristic Curve Analysis

SUGGESTED ACTIVITIES

E. Assignment Sheets

   1. Assignment Sheet #1--Determine the Operating Conditions of a Vacuum Tube Circuit

   2. Assignment Sheet #2--Label Vacuum Tube Pins

F. Answers to assignment sheets

G. Job sheets

   1. Job Sheet #1--Test a Vacuum Tube Using a Tube Tester

   2. Job Sheet #2--Check a Vacuum Tube with an Ohmmeter

H. Test

I. Answers to test

III. Unit references

A. Chirlian, Paul M. *Electronic Circuits: Physical Principles, Analysis, and Design*. New York: McGraw-Hill Book Co., 1971.

B. Driscoll, Edward F. *Industrial Electronics: Devices, Circuits and Applications*. Chicago: American Technical Society, 1976.

C. *Electrical Maintenance: Introduction to Electricity and Electronics*, Unit I. Barrington, Illinois: TPC Training Systems, Division of Technical Publishing Company, 1975.

D. *Radio Fundamentals*. U.S. Army Special Text ST-11-173. Fort Monmouth, New Jersey: U.S. Army Signal School, 7 March 1961.

VACUUM TUBES
UNIT VI

INFORMATION SHEET

I. Terms and definitions

A. Transconductance--Measure of vacuum tube's ability to conduct current as expressed in units of conductance called *mhos*

(NOTE: Transconductance is the inverse of the tube's resistance.)

B. Cathode-ray tube--Vacuum tube in which electron ray is directed to a screen where it activates light-emitting material

C. Visual display unit--Cathode-ray tube used with a computer to display messages, symbols, and computer graphics

D. Amplification factor--Measure of vacuum tube's ability to amplify voltage as determined by the output voltage divided by the input voltage under particular conditions

E. Plate resistance--Measure of vacuum tube's resistance to current flow as determined by the tube's voltage divided by current under particular conditions

F. Electron tube--Tube that functions with the internal control of an electron beam

EXAMPLES: Cathode-ray tubes, vacuum tubes, photo tubes

G. Bias--DC voltage applied to tube's elements to establish operating conditions about which signals and variable input voltages will influence tube's behavior

(NOTE: Bias is also known as *grid bias, C bias*, and *direct grid bias*.)

H. Secondary emission--Electrons emitted from an element when it is bombarded by other electrons

I. Getter--Vacuum tube element heated to its burning temperature during tube's manufacturing process

(NOTE: The element burns any remaining oxygen left in the envelope after being evacuated.)

J. Load line--Line relative to the tube's bias drawn across a tube's characteristic curves showing the relationship that voltages and currents will follow for the particular load which the tube is supplying

(NOTE: Methods for drawing the load line vary depending on the circuit's complexity.)

INFORMATION SHEET

K. Operating point--Specific point at which tube will operate with no input signal

(NOTE: Operating point can be located and marked on a set of tube characteristic curves and is sometimes called the *quiescent point*.)

L. Capacitively coupled--Connected through a capacitor, thus isolated from DC while allowing AC signals to be transferred

(NOTE: It is incorrect to say that "capacitors block DC but allow AC to pass." Actually, capacitors allow alternating power to be transferred but not static power. Current does not pass through the capacitor in either case.)

M. Grid leak bias--Method of establishing a grid voltage through the current flow that leaks onto grid from within vacuum tube

N. Ohm's Law--Relationship between current, resistance, and voltage; expressed mathematically as $E=IR$, $I=\frac{E}{R}$, or $R=\frac{E}{I}$

O. Voltage drop--Reduction in voltage; usually understood to be due to current flow through a resistance given by Ohm's Law

P. Megohm--One million ohms

Q. Microampere--One one-millionth of an ampere

R. Parameter--Mathematical expression that characterizes a device's behavior

S. Algebraic--Pertaining to mathematical laws whereby the addition of two negative numbers results in a sum with a negative sign, and the addition of a negative number and a positive number results in a difference with the sign of the larger number

T. Delta--Greek letter (Δ) indicating the change in the value of the quantity to be considered

U. Plate characteristic curve--Graph showing the relationship between plate voltage, grid voltage, and plate current for a particular type of vacuum tube at specified conditions (Transparency #5)

II. Abbreviations and symbols associated with vacuum tubes

A. C--Capacitor

B. G_m--Transconductance

C. CRT--Cathode-ray tube

D. VDU--Visual display unit

E. μ--Amplification factor; micro (10^{-6})

INFORMATION SHEET

F. R_p--Plate dynamic resistance

G. E_{G_1}--Control grid voltage

H. E_{G_2}--Screen grid voltage

I. E_{G_3}--Supressor grid voltage

J. R--Resistor

K. Ω--Ohm

L. K--Kilo (10^3)

M. M--Mega (10^6)

N. m--Milli (10^{-3})

O. V--Volt

P. I--Current

Q. Δ--Delta; change

R. E--Voltage, as in E=IR

S. Pk-Pk--Peak-to-peak

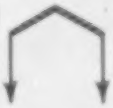
T. μA--Microampere

(NOTE: Letters may appear as capitals, such as G_m, or small letters, such as g_m. If parameters are involved, capital letters are usually intended for static or DC characteristics. Small letters are intended to represent dynamic or AC characteristics.)

III. Electron tube element symbols (Figures 1-9)

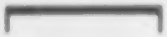
A. Filament

FIGURE 1



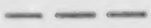
B. Cathode

FIGURE 2



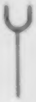
INFORMATION SHEET

C. Grid

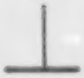
FIGURE 3 

D. Photo cathode

FIGURE 4

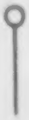


E. Plate

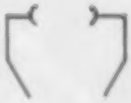
FIGURE 5 

F. Cold cathode

FIGURE 6



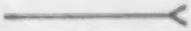
G. Beam forming plates

FIGURE 7 

H. Gas filled

FIGURE 8

I. Eye tube deflection plate

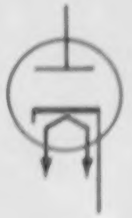
FIGURE 9 

INFORMATION SHEET

IV. Vacuum tube circuit symbols (Figures 10-26)

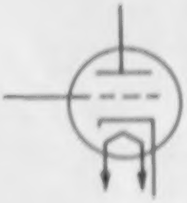
A. Diode; indirectly heated cathode

FIGURE 10



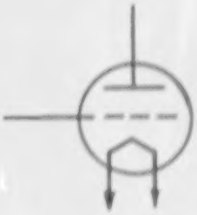
B. Triode; indirectly heated cathode

FIGURE 11



C. Triode; directly heated cathode

FIGURE 12

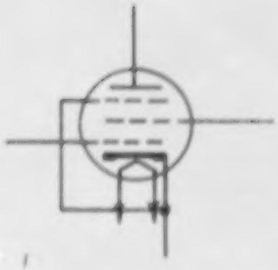


(NOTE: Virtually all tubes are available in directly and indirectly heated cathode types but are not interchangeable.)

INFORMATION SHEET

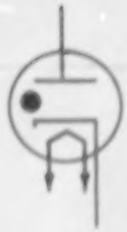
D. Pentode

FIGURE 13



E. Thyratron

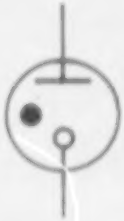
FIGURE 14



(NOTE: The dot in the envelope of any tube denotes a gas filled tube.)

F. Gas regulator tube; cold cathode rectifier

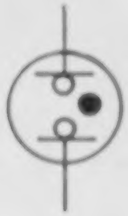
FIGURE 15



INFORMATION SHEET

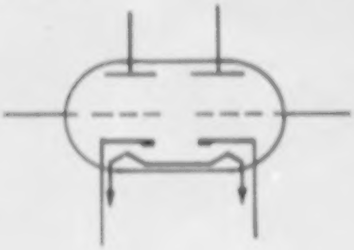
G. Neon tube; lamp

FIGURE 16



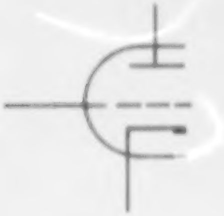
H. Dual triode

FIGURE 17



I. One-half of a dual triode shown by itself, as in a schematic

FIGURE 18

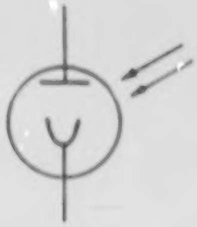


(NOTE: Filaments are often not shown on the tube symbol in schematics, but are shown at the power supply connection.)

INFORMATION SHEET

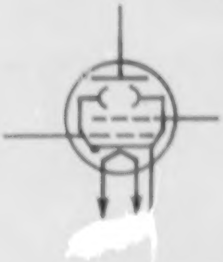
J. Photo tube

FIGURE 19



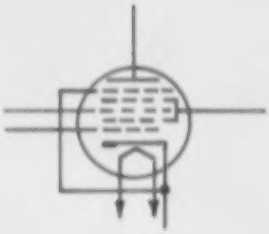
K. Beam power tube

FIGURE 20



L. Pentagrid

FIGURE 21

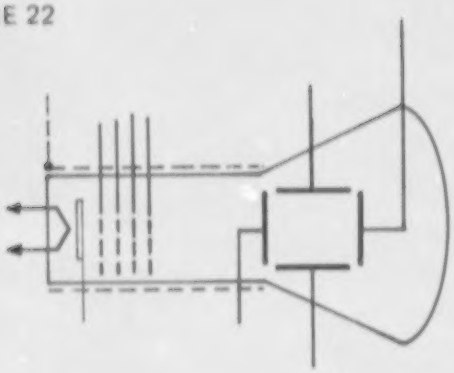


(NOTE: The connection between the cathode and the suppressor grid may be built into the tube and shown inside the envelope.)

INFORMATION SHEET

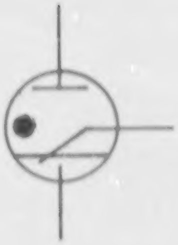
M. Cathode-ray tube

FIGURE 22



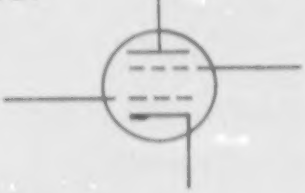
N. Ignitron

FIGURE 23



O. Tetrode

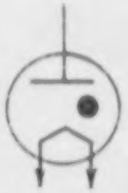
FIGURE 24



INFORMATION SHEET

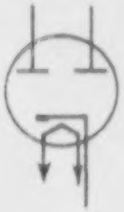
P. Mercury vapor rectifier

FIGURE 25



Q. Dual diode rectifier

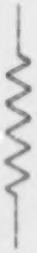
FIGURE 26



V. Electronic component circuit symbols (Figures 27-31)

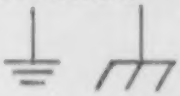
A. Resistor

FIGURE 27



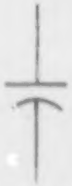
B. Ground connections

FIGURE 28



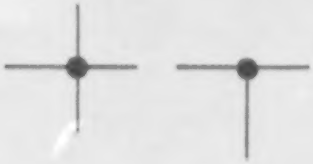
C. Capacitor

FIGURE 29



D. Conductors connected

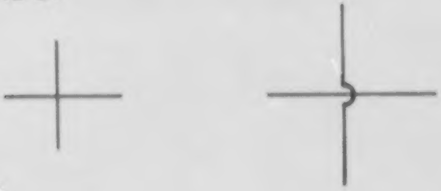
FIGURE 30



INFORMATION SHEET

E. Conductors not connected

FIGURE 31



VI. Elements in a pentode vacuum tube (Transparencies #1 and #2)

A. Plate or anode

B. Supressor grid

C. Screen grid

D. Control grid

E. Cathode

F. Heater or filament

G. Envelope or tube

VII. Disadvantages of vacuum tubes compared to solid-state devices

A. Larger

B. Produce more heat

C. Require larger and heavier power supplies

D. Less energy-efficient

E. Must operate at higher voltages

F. Must be replaced more often

G. Require, like most tube-type equipment, more frequent maintenance and calibration

(NOTE: Due to the rapid development of solid-state technology, there are virtually no advantages to tubes compared to solid-state devices. A few special applications for vacuum tubes, such as cathode-ray tubes, have not been replaced by solid-state technology, but progress is being made in these areas.)

INFORMATION SHEET

VIII. Purposes of vacuum tube primary elements

A. Plate or anode--Attracts electrons across the gap and returns them to the external circuit

B. Suppressor grid--Suppresses secondary emission electrons that are driven out of the plate when it is bombarded with the primary beam; grid repells electrons back to plate

C. Screen grid--Improves high frequency operation in reducing capacitance effect between electrodes by dividing gap between them

D. Control grid--Causes variations in electron beam so that its voltage is varied

E. Cathode--Supplies electrons from the external circuit into the tube

F. Heater or filament--Heats cathode, causing electrons to be released from material

G. Envelope or tube--Keeps air from entering vacuum or keeps a particular gas from escaping

IX. Vacuum tube general biasing requirements

A. Plate must be more positive than cathode in order to attract electrons

B. Cathode must be less positive than plate, even if zero or positive is compared to ground

EXAMPLE: The plate of a tube could be 200 volts positive as measured from ground, and the cathode could be 25 volts positive as measured from ground. The relative voltage of the cathode, as measured from the plate, would be 175 volts negative.

(NOTE: Voltage must always be thought of as a measurement between points, or as one point compared to another. This concept is always implied in the term and is usually understood to be referenced to ground.)

C. Control grid is usually a few volts negative, compared to cathode, so that it can vary the flow of passing electrons but not attract a large current

D. Screen grid is always positive compared to the cathode

E. Suppressor grid is usually connected directly to cathode to suppress secondary emission from plate

X. Determining parameters of vacuum tubes

A. Locate the point on the graph where the two known values intersect

INFORMATION SHEET

B. Determine the value of the third parameter for that point

(NOTE: A technician can quickly measure a vacuum tube's plate voltage and grid voltage; however, plate voltage is more difficult to measure.)

EXAMPLE: Suppose plate voltage is measured at 200 volts on a type 6SJ7 tube. The grid voltage is measured at -3 volts. The point on the graph where the grid voltage is -3 and the plate voltage is 200 volts also corresponds to a plate current of 3 milliamperes, assuming other conditions are as specified (Transparency #3).

XI. Determining vacuum tube plate resistance--Use Ohm's Law $R = \frac{E}{I}$

EXAMPLE: At the circled point on the graph of the type 6SJ7 tube, plate voltage is 200 volts, and plate current is 3 milliamperes (Transparency #3)

$$R = \frac{E}{I}$$

$$= \frac{200V}{3mA}$$

$$= \frac{200}{3 \times 10^{-3}}$$

$$= 66.67 \times 10^{3}$$

$$= 67 \text{ Kohms}$$

XII. Steps in drawing a load line on a plate dynamic characteristic curve (Transparencies #4 and #6)

A. Find and mark the point on the zero milliamperes plate current line where the plate voltage is equal to the supply voltage

(NOTE: This is called the cutoff point and represents the maximum voltage across the tube.)

B. Divide the supply voltage by the plate load resistor to find the maximum plate current of the tube

C. Find and mark the point on the plate zero voltage line of the maximum plate current found in step B

D. Draw the load line between the voltage and current points on the characteristic curve

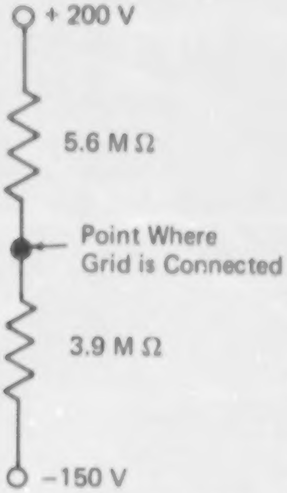
INFORMATION SHEET

XIII. Determining the operating point of a simple vacuum tube (Transparencies #4 and #6; Assignment Sheet #1)

A. Isolate the grid circuit to one containing only the elements through which DC bias currents pass

(NOTE: DC current does not pass through capacitors. Assume that no DC current is leaked to the grid from the tube in this case. In this elementary analysis, the small current called *grid leak* that may leak into the grid circuit will be disregarded. Some circuits utilize this leakage current to establish a DC bias for the grid. This is called *grid leak bias*.)

FIGURE 32



B. Analyze the circuit in Figure 32 to determine the voltage on the grid

1. Use Ohm's Law to find the current

EXAMPLE: The voltage across the two resistors is 350 volts total. The total resistance is 9.5 megohms. Using Ohm's Law, the current through the two resistors can be found as follows

$$E = IR$$

$$350\text{ V} = I \times 9.5\text{ M}\Omega$$

$$I = \frac{350\text{ V}}{9.5\text{ M}\Omega}$$

$$= \frac{350}{9.5 \times 10^{6}}$$

$$= 36.84 \times 10^{-6}$$

$$= 36.84\ \mu\text{A}$$

INFORMATION SHEET

2. Use Ohm's Law to find the voltage drops

   EXAMPLE: Since current through the 5.6 megohm resistor is 36.84 microamperes, voltage drop across it is E = IR, or (5.6 x 10^6) (36.84 x 10^{-6}) or 206.3 volts.

3. Subtract the voltage drops from the voltage supply to find the remaining voltage at the grid

   EXAMPLE: Voltage supplied at the top of the 5.6 megohm resistor is 100 volts. The voltage drop is 206.3 volts. 200 volts less 206.3 volts results in -6.3 volts. The voltage at the grid is -6.3 volts. This is the operating point. It is shown on the graph of Transparency #6 as point #1.

XIV. Determining the output voltage variation of the vacuum tube circuit (Transparencies #4 and #6)

A. Mark the operating point on the load line

EXAMPLE: The operating point for the circuit of Transparency #4 was determined to be -6.3 volts. It is marked on the graph as point #1. The approximate position is estimated between -6 and -8 volts.

B. Mark the point of the maximum positive voltage variation of the input

(NOTE: This point is determined by the algebraic addition of the maximum positive input variation and the operating point.)

EXAMPLE: The input signal is 10 volts Pk-Pk. This is 5 volts positive and 5 volts negative, alternating. The maximum positive is found by adding +5 volts and -6.3 volts to get -1.3 volts. Notice that the addition of unlike voltage signs results in the difference, not the sum. This point is marked on the graph as point #2. The approximate position is estimated between 0 and -2 volts.

C. Mark the point of the maximum negative voltage variation of the input

(NOTE: This point is determined by algebraically adding the maximum negative input variation to the operating point.)

EXAMPLE: The -5 volt input variation is added to the -6.3 volt operating point to get the maximum negative variation of -11.3 volts. This point is marked on the load line as point #3. The approximate position is estimated between -10 volts and -12 volts.

INFORMATION SHEET

D. Mark the corresponding three points on the plate voltage scale

(NOTE: These points are the output voltages corresponding to the input voltages. To find the points, draw a vertical line down to the plate voltage scale.)

EXAMPLE: A -1.3 volt input corresponds to a 130 volt output; a -6.3 volt input gives a 195 volt output; and a -11.3 volt input results in an output of 265 volts. These points are marked as points #4, #5, and #6 on the graph.

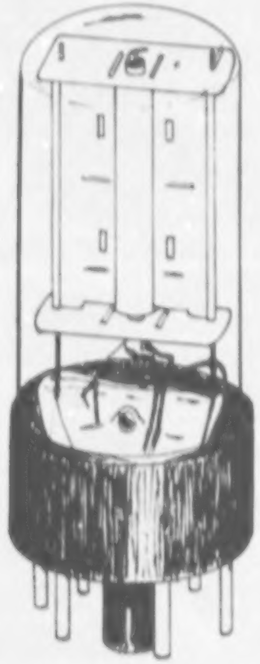
(NOTE: Output voltage is then 130 volts to 265 volts, or 135 volts Pk-Pk. An input signal of 10 volts Pk-Pk amplifies to a 150 volt Pk-Pk signal.)

XV. Types of vacuum tubes (Figures 33-40)

A. Ordinary vacuum tube

(NOTE: This tube is two to four inches high and has a glass envelope and a plastic or Bakelite® base.)

FIGURE 33

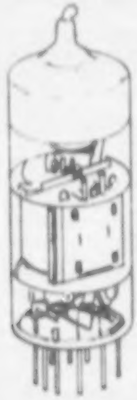


INFORMATION SHEET

B. Miniature glass vacuum tube

(NOTE: This tube is one to four inches high and has a glass envelope and base.)

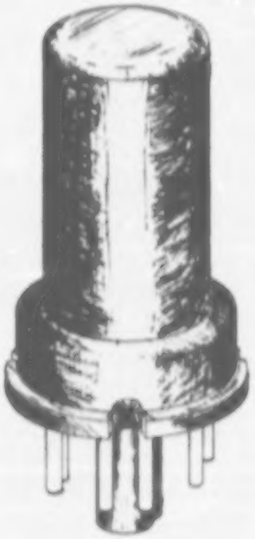
FIGURE 34



C. Metal case vacuum tube

(NOTE: This tube is two to six inches high and has a metal envelope.)

FIGURE 35

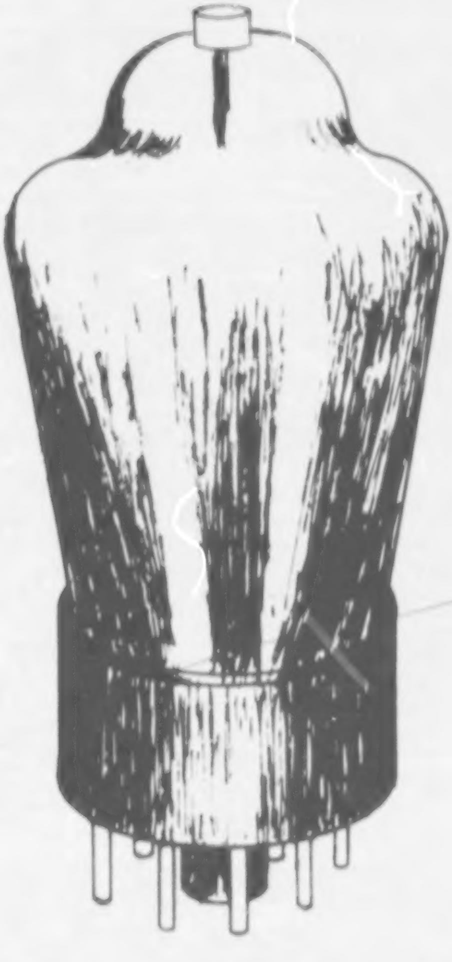


INFORMATION SHEET

D. Beam power tube

(NOTE: This type of tube is four to twelve inches high and has a cap connection on top.)

FIGURE 36

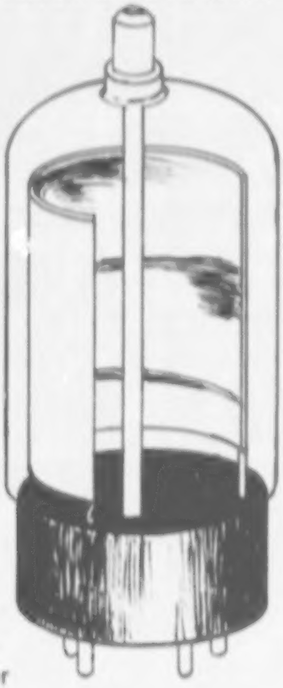


INFORMATION SHEET

E. Photo tube

(NOTE: This type of tube is two to six inches high. Its reflector and sensor are usually evident. It usually has a cap connection on top and may have a cap connection on the bottom instead of pins.)

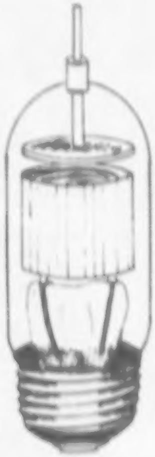
FIGURE 37



F. Mercury vapor rectifier

(NOTE: This type of tube is four to six inches high and usually has a cap connector on top, and screw-in base. Heavy electrodes are evident.)

FIGURE 38

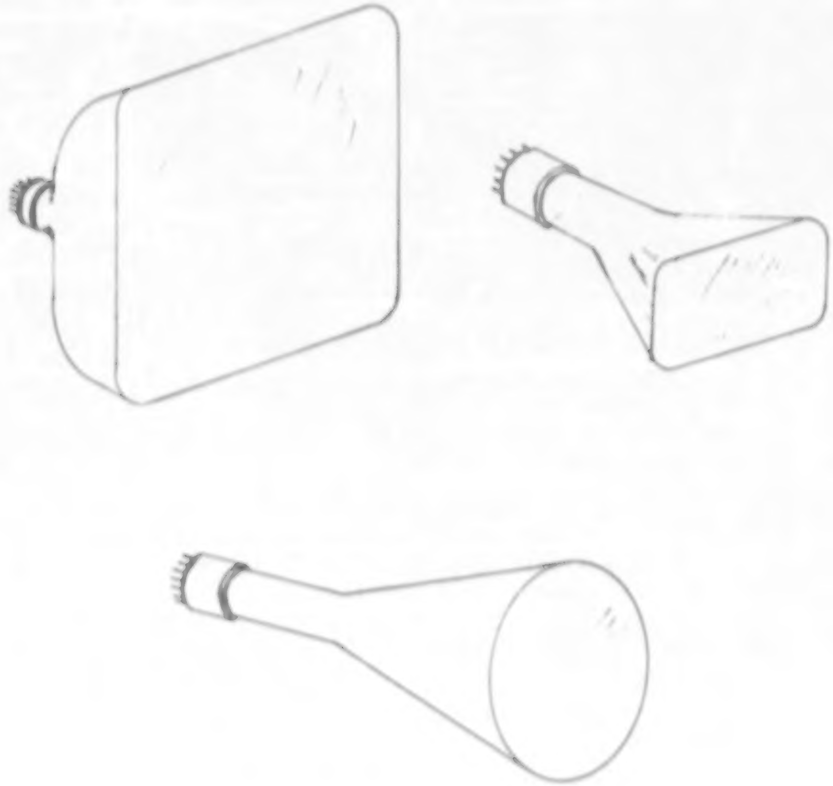


INFORMATION SHEET

G. Cathode-ray tube (CRT)

(NOTE: This type of tube is twelve to twenty inches long. Its screen may be of many sizes or shapes. Cathode-ray tubes are used in oscilloscopes, analyzing scopes, closed circuit television monitors, and visual display units for computers. This type of electron tube is used extensively in industry and will probably be the last type to be effectively replaced with solid-state devices. However, development of a solid-state replacement is already underway.)

FIGURE 39

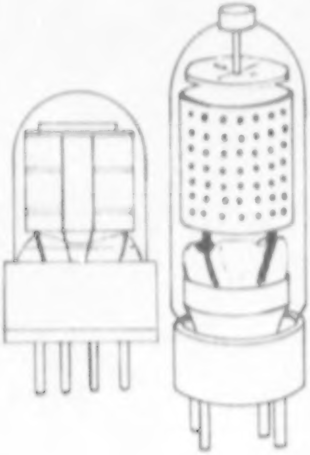


INFORMATION SHEET

H. Thyratron

(NOTE: This type of tube is one to six inches high or larger and may resemble an ordinary vacuum tube. It may have a cap connector on top. Electrodes may resemble a mercury-vapor rectifier.)

FIGURE 40



XVI. Mathematical formulas and conditions of principal vacuum tube parameters

A. Plate resistance

$R_p = \frac{\Delta E_p}{\Delta I_p}$ --With grid current constant

B. Amplification factor

$\mu = \frac{\Delta E_p}{\Delta E_g}$ --With plate current constant

C. Transconductance

$G_m = \frac{\Delta I_p}{\Delta E_g}$ --With plate voltage constant

INFORMATION SHEET

XVII. Formula for finding the relationship between vacuum tube parameters--$\mu = G_m R_p$

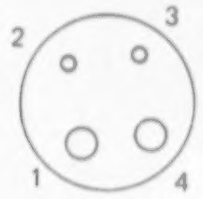
XVIII. Vacuum tube pins (Assignment Sheet #2; Figures 41-46)

(NOTE: Count clockwise from pin to pin, looking at the tube with the pins pointed directly at you.)

A. Four pin

(NOTE: Pin 1 is left largest pin.)

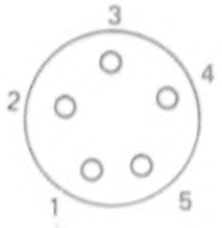
FIGURE 41



B. Five pin

(NOTE: Pin 1 is the left closest pin.)

FIGURE 42

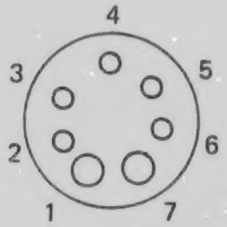


INFORMATION SHEET

C. Seven pin

(NOTE: Pin 1 is left largest pin.)

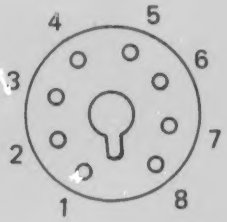
FIGURE 43



D. Eight pin

(NOTE: Pin 1 is left of the key.)

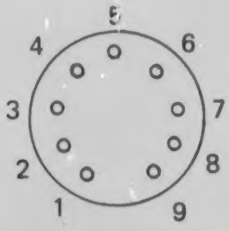
FIGURE 44



E. Nine pin

(NOTE: Pin 1 is left of the gap.)

FIGURE 45

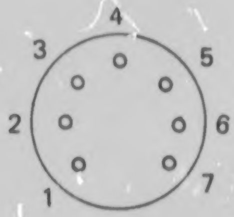


INFORMATION SHEET

F. Seven pin

(NOTE: Pin 1 is left of the gap.)

FIGURE 46



XIX. Vacuum tube identification type-code

A. First number or pair of numbers identifies the filament nominal voltage

B. Intermediate letters identify the purpose

C. Second number identifies the number of pins

D. Suffixes identify special applications and improved versions

EXAMPLES: 12AU7--A tube requiring 12.6 volts on the filament and having 7 pins

6AU7--The same as a 12AU7 except for the filament voltage; if the filament voltage were changed, it could be substituted

(NOTE: Not all tubes follow this numbering system.)

XX. Common causes of vacuum tube failure

A. Filament failure

(NOTE: Filament wires gradually lose molecules, weaken at one point, and burn out. Excessive jarring may rupture the filament, or too much filament current may burn it out.)

B. Gassy tube

(NOTE: If the envelope leaks, air is drawn into the tube. Internal elements give off gas when overheated by excessive current.)

C. Shorted elements

(NOTE: Heated elements or wires in the envelope may sag and touch. Heater-to-cathode insulation may break down.)

INFORMATION SHEET

D. Loose elements

(NOTE: When elements are not welded properly, they vibrate, causing open or short circuits in the tubes and noises in circuits in which the tubes are used. Jarring or heating may also loosen internal-element welds.)

Elements of a Vacuum Tube Pentode
(Schematic)

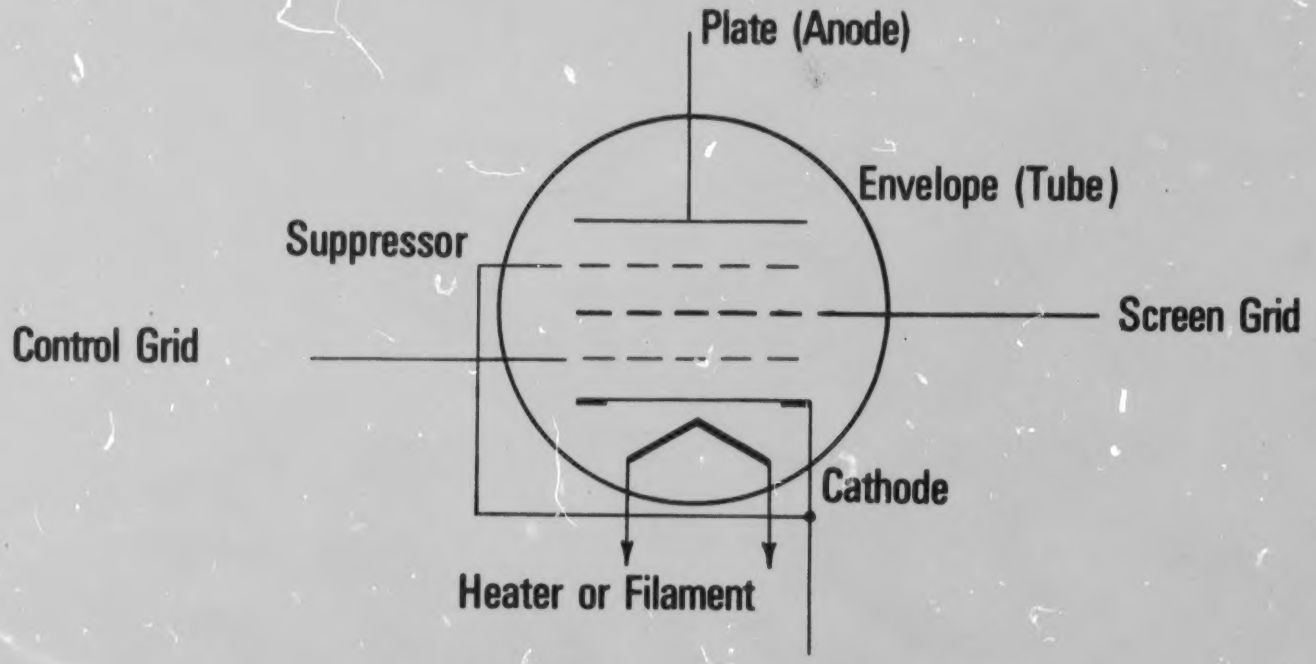
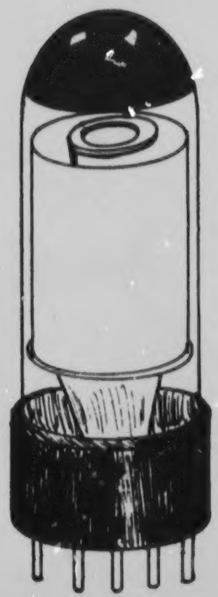
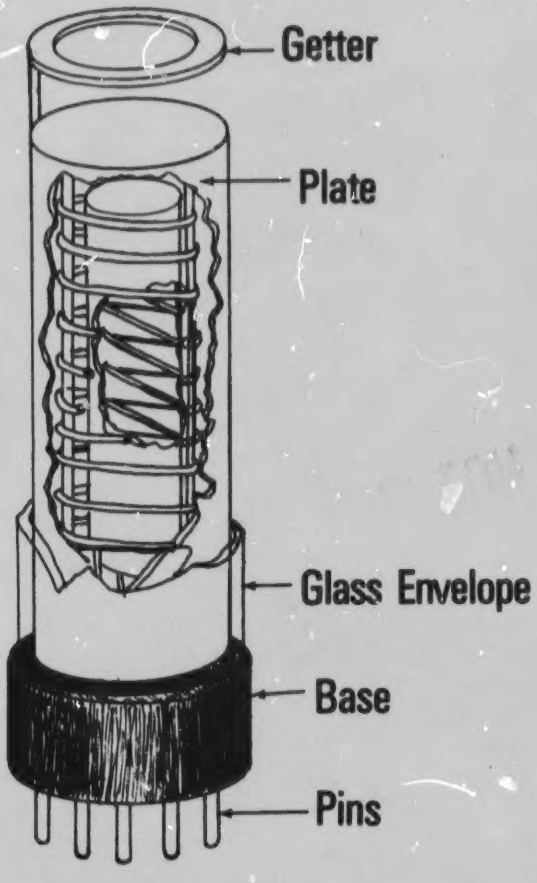


Plate (Anode)
Envelope (Tube)
Suppressor
Screen Grid
Control Grid
Cathode
Heater or Filament

Elements of a Vacuum Tube Pentode (Diagram)



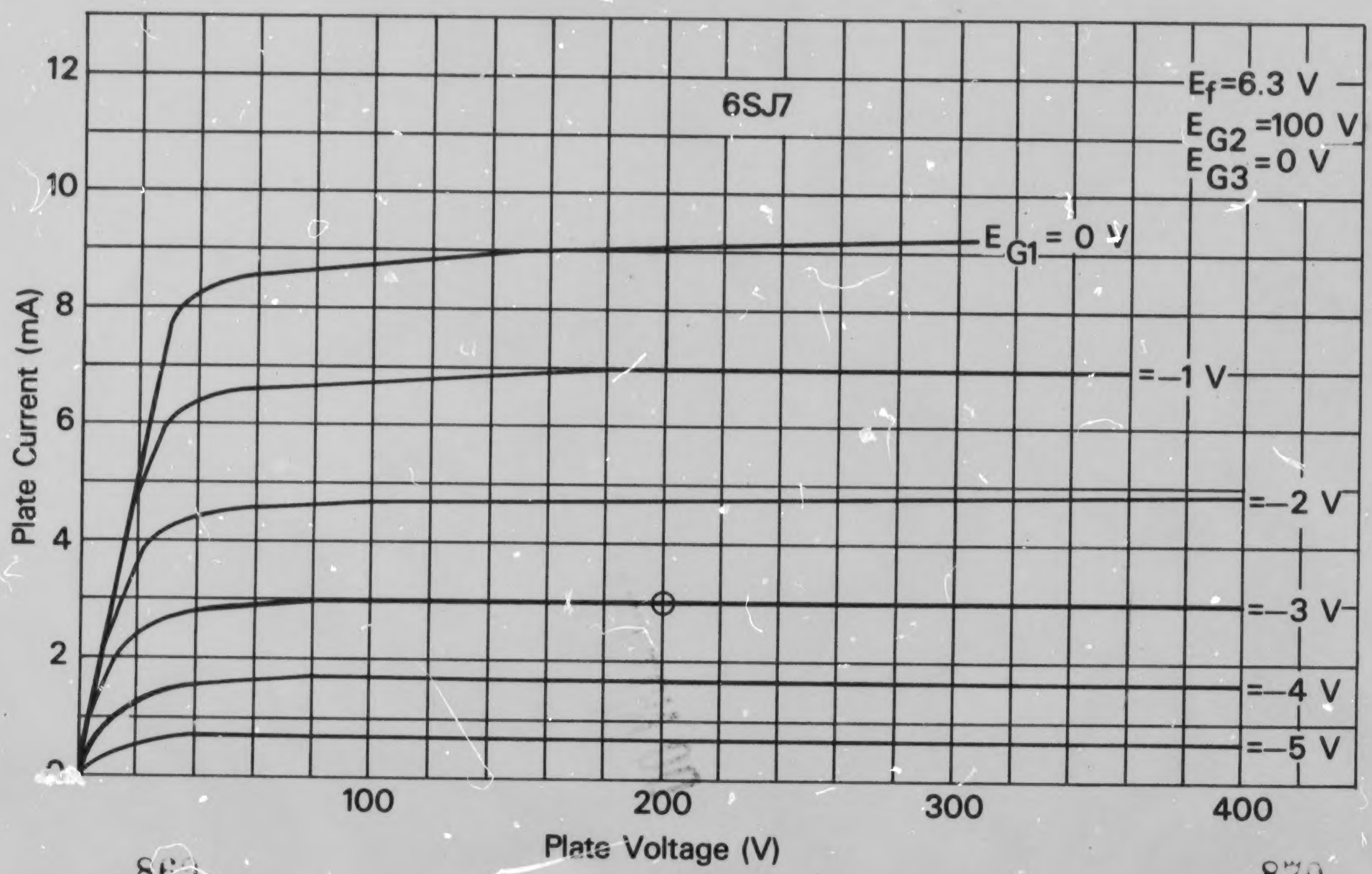
Vacuum Tube


Getter
Plate
Glass Envelope
Base
Pins

Cutaway View
of Typical
Electron Tube

5

Characteristic Curve 6SJ7



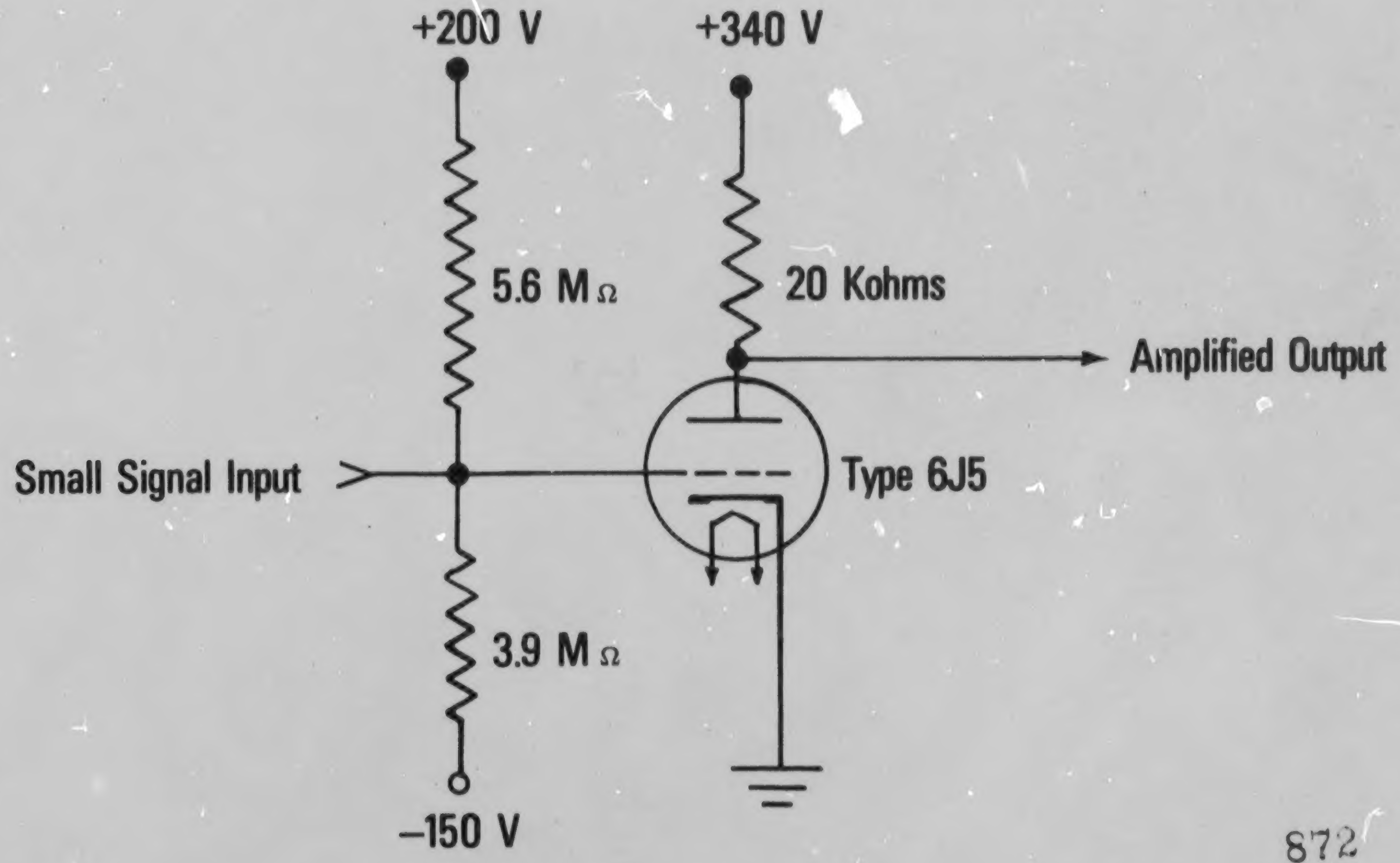
TM #3

869

870

IIEE - 343-E

Amplifier Circuit


+200 V
+340 V
5.6 MΩ
20 Kohms
Amplified Output
Small Signal Input
Type 6J5
3.9 MΩ
–150 V

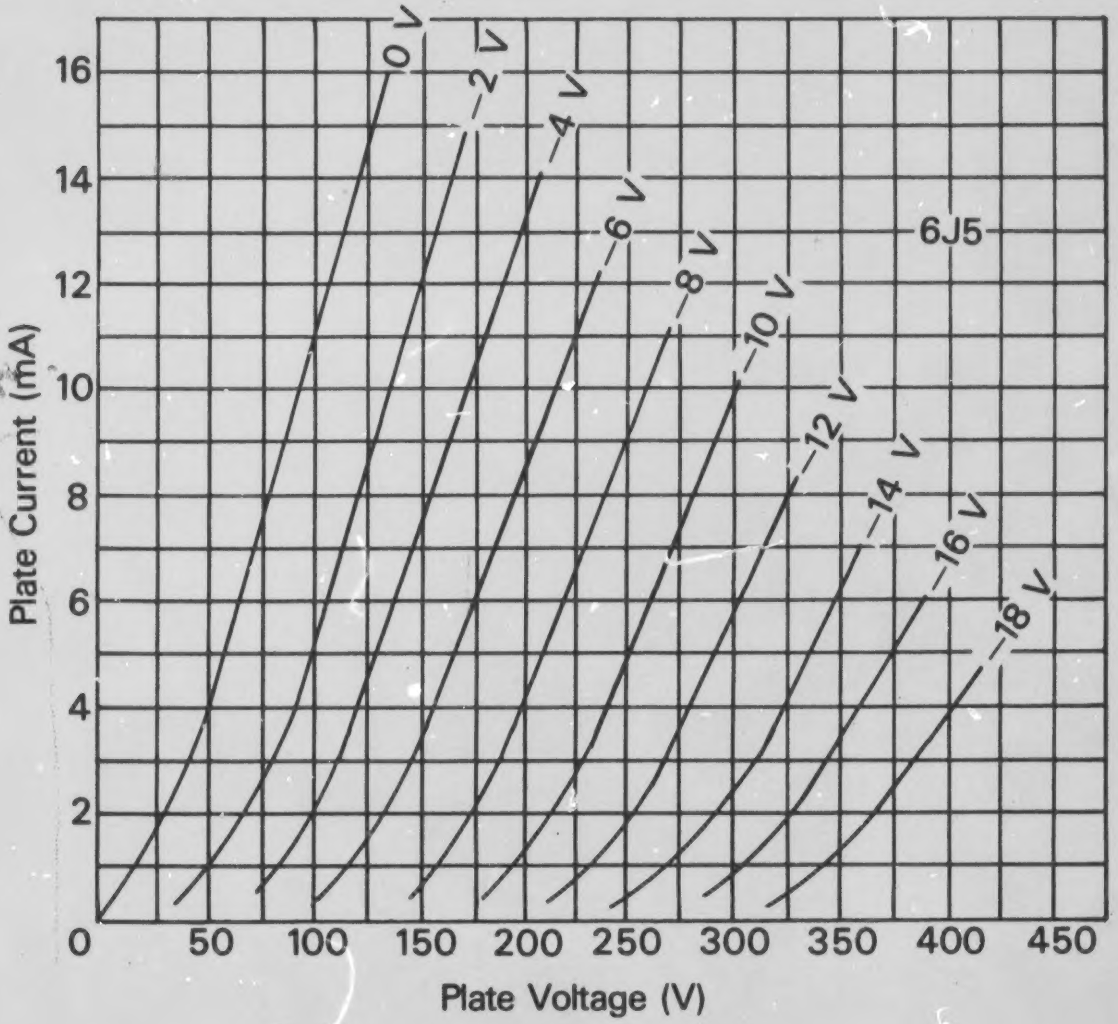
TM #4

871

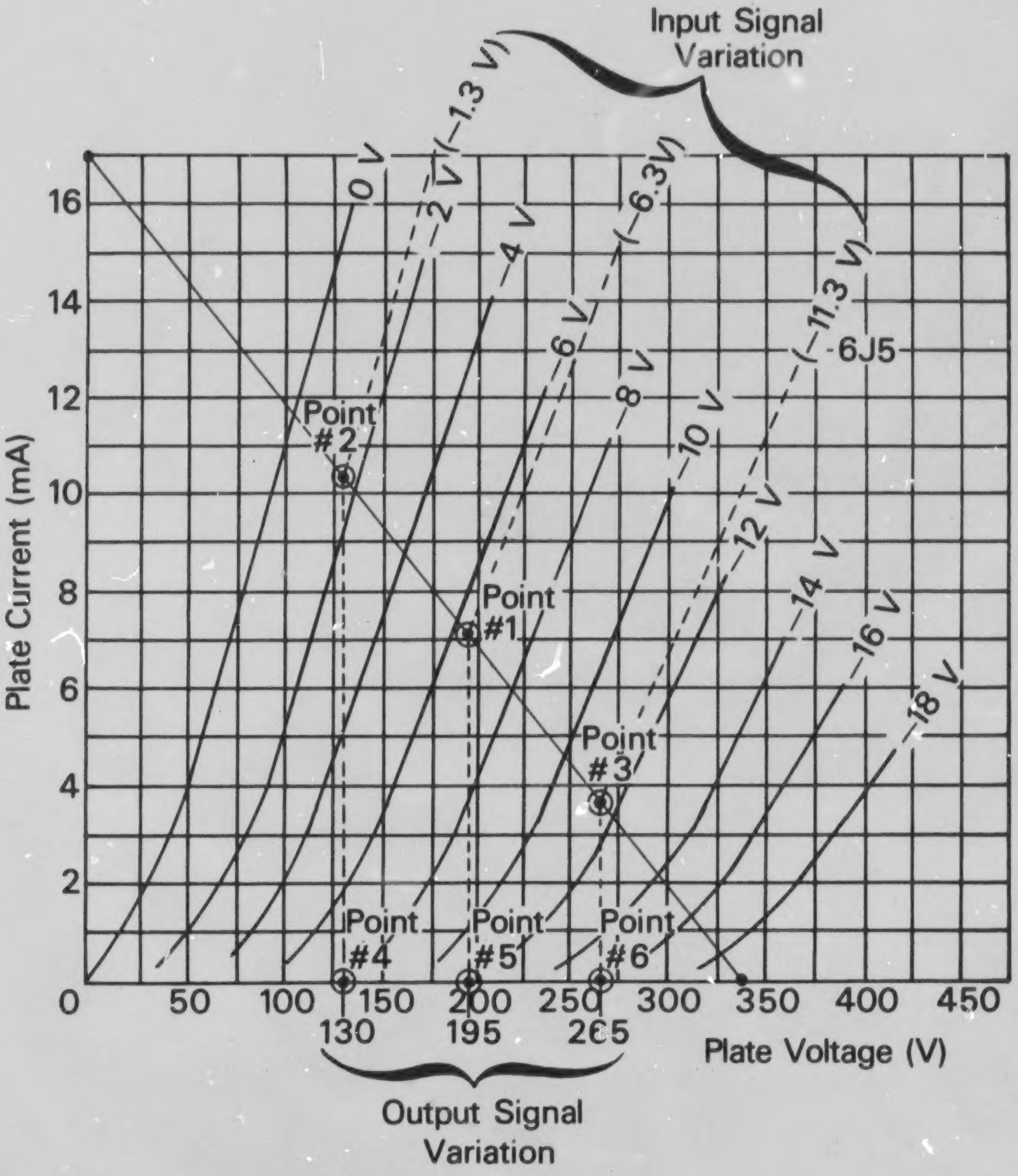
872

IIEE - 345-E

Characteristic Curve 6J5



Characteristic Curve Analysis



VACUUM TUBES
UNIT VI

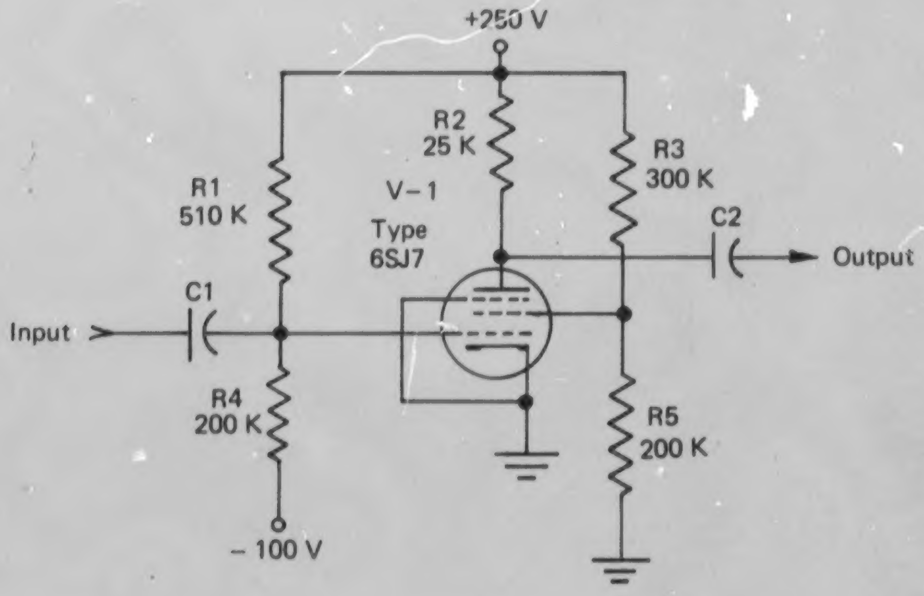
ASSIGNMENT SHEET #1--DETERMINE THE OPERATING CONDITIONS OF A VACUUM TUBE CIRCUIT

NAME ______________________________ SCORE ______________

Vacuum tubes are rapidly becoming obsolete because of the advantages of solid-state devices. However, industries still have much vacuum tube equipment which has not been replaced because of the size of the investment, the costs of replacement, or the lack of suitable replacement equipment on the market. It is important then, that the technician be able to properly maintain vacuum tube equipment. In troubleshooting such equipment, the technician must often analyze the circuit schematics, and refer to the tube manufacturer's specifications and characteristic curves to determine how the device should be operating. Measurements can then be made to compare actual voltages to design voltages. With further analysis and troubleshooting techniques, the problem can be determined.

Use the methods described in this unit to answer the questions following Figure 47. The tube characteristic curves are shown on Transparency #2. Review previous material if necessary. Remember DC is not transferred across capacitors. Disregard possible grid leakage currents.

FIGURE 47



ASSIGNMENT SHEET #1

A. If the tube is not conducting, what is the voltage of the plate? ____________________

(NOTE: If the lesson material is yours to keep, you may wish to mark on the graph of Transparency #2 as you solve these problems.)

B. What is the voltage of the cathode? ____________________

C. The tube ratings are specified at E_{G_2} = 100 V. Is this voltage the same as that in the circuit?

____

D. If the tube were conducting freely, and it had no resistance to current flow, what would the current in the plate circuit be? ____________________

E. What is the voltage on the grid with no signal input and no grid leakage current?

____

F. What is the voltage on the suppressor grid? ____________________

G. Which grid voltage, E_{G_1}, E_{G_2}, or E_{G_3}, determines the operating point? ____________

H. If the input signal to the grid is 2.8 volts AC Pk-Pk, what is the resulting output signal?

Output signal = From about __________ volts, to about __________ volts

I. Voltage gain is found by dividing the change in output voltage by the change in input voltage. For example, the change in the output voltage shown on Transparency #4 was 135 volts (265 minus 130 volts). The change in the input voltage was 10 volts. It could be said that the circuit had a voltage gain of 13.5 because 135 divided by 10 equals 13.5. Do a similar analysis to find the voltage gain of the circuit in Figure 47.

Voltage gain = ____________________

J. What is the total current required for the circuit when it has no input or output signal?

____

(NOTE: Add the currents of the control grid path, the plate current at the operating point, and the screen grid path.)

VACUUM TUBES
UNIT VI

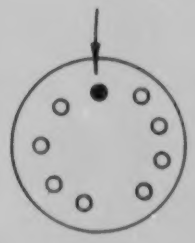
ASSIGNMENT SHEET #2--LABEL VACUUM TUBE PINS

NAME ______________________ SCORE ______________

In order to troubleshoot tube-type equipment, a technician may inject an AC signal from a generator at the grid of a tube and then monitor the output at the plate using an oscilloscope. There the signal will be viewed to check for amplification and possible distortion. Whether the technician performs this test or merely checks voltages, it is necessary to quickly identify the numbers of the tube and the corresponding socket.

In the problems that follow, label the tube or tube socket pin marked by the arrow. Write your answers in the spaces provided. Have your instructor check them when you have finished.

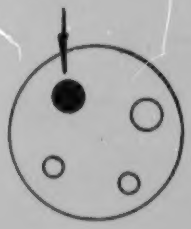
FIGURE 48



Tube Base

A. ______________________

FIGURE 49



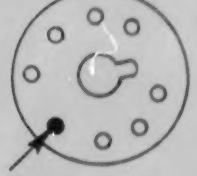
Tube Base

B. ______________________

4

ASSIGNMENT SHEET #2

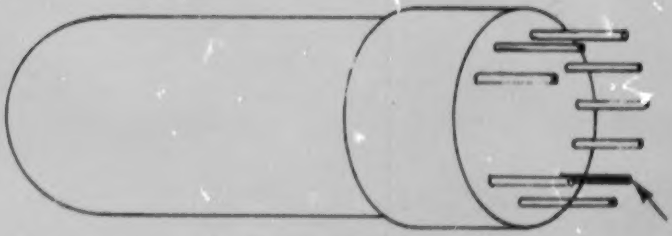
FIGURE 50



3. Tube base

C. ______________________

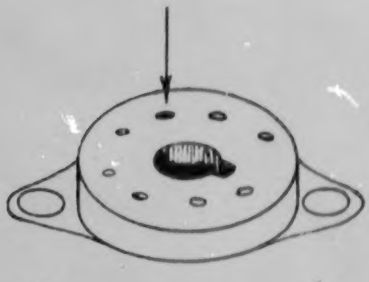
FIGURE 51



4. Tube

D. ______________________

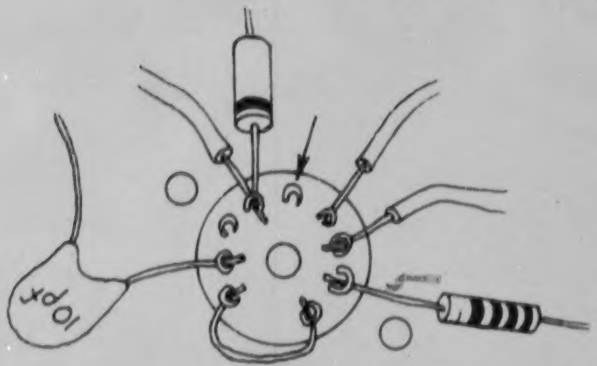
FIGURE 52



5. Tube Socket (Top)

E. ______________________

FIGURE 53



6. Tube Socket (Bottom, Inside Chassis)

F. ______________________

VACUUM TUBES
UNIT VI

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 250 V

(NOTE: If I = O, then E = O and there is no voltage drop. Whatever voltage is on one side of a resistor is also on the other side if there is no current flow.)

B. Zero volts

(NOTE: It is connected directly to ground.)

C. Yes

D. 10 mA

E. -1.41 V

F. Zero V

(NOTE: It is tied directly to ground.)

G. E_{G1}, the control grid

(NOTE: If the other grid voltages are not as specified, then the characteristic curve graph does not apply.)

H. From about 42 volts to about 170 volts

I. About 46

J. 10.99 mA (10 mA, .49 mA, .5 mA)

Assignment Sheet #2

A. Pin #5

B. Pin #4

C. Pin #4

D. Pin #7

E. Pin #3

(NOTE: The socket is numbered counterclockwise, looking at the top, to match the clockwise numbering on the tube's bottom.)

F. Pin #9

VACUUM TUBES
UNIT VI

JOB SHEET #1--TEST A VACUUM TUBE USING A TUBE TESTER

I. Equipment and materials

A. Electron tube--Any common type

EXAMPLES: 12AV6, 12BA6, 6AK5

B. Tube tester--Capable of testing for shorts as well as amplification or transconductance

C. Operating instructions for the particular tester, including a list of various tube types and their required settings

D. If pins are bent, pin straightener for particular tube to be tested

II. Procedure

A. Examine tube for a broken envelope or base and for bent pins

B. Straighten any bent pins using the pin straightener

(NOTE: If a pin straightener is not available use a pair of needle-nose pliers to gently straighten any bent pins. Do not clamp heavily or the pliers will nick the pin.)

C. Find tube type number

D. Look through tube listing to find the socket or adapter on the tester and where it should be inserted

E. Install tube in correct tube socket

F. Set tester controls as indicated

G. Double check controls to be sure they are correct

H. Follow directions printed on tester or with the tube listings to turn on the unit and test the tube

(NOTE: If the tube is a dual tube, procedure will be listed twice with slightly different control settings. Test both halves. Allow 30 seconds for warm up time.)

I. Test for a loose internal problem, if tube is experiencing intermittent failures

JOB SHEET #1

J. Gently thump side of tube while the test for conductance is underway

(NOTE: Conductance is underway while a meter display is present and usually requires that a pushbutton be held down. If the tube has a loose component, the meter will flicker, the "short" indicator may flash, or the filament may be seen to go out. Report findings to the instructor.)

K. Put equipment and materials away

VACUUM TUBES
UNIT VI

JOB SHEET #2--CHECK A VACUUM TUBE WITH AN OHMMETER

I. Equipment and materials

- A. Multimeter
- B. Electron tube
- C. Reference data or manufacturer's specifications showing tube elements and pin connections

II. Procedure

- A. Determine which pins of the tube connect to which elements

  EXAMPLES: Cathode, plate, heater

- B. Measure across the heater pins

  (NOTE: If the measurement reads "infinite resistance," the heater is probably burned out. Most heaters should read from 2 to 200 ohms depending on the voltage rating of the heater. Higher voltage-rated heaters, such as a 12AL5, will measure more ohms than lower voltage-rated heaters, such as 3AL5.)

- C. Measure between pins of adjacent elements

  EXAMPLES: Cathode to control grid, control grid to screen grid, screen grid to plate

  (NOTE: These measurements should read infinity on the ohmmeter because the elements should not be connected. Report your findings to the instructor. This check does not ensure that a tube is in good working order. It serves only to check for shorts and open filaments which are common tube problems. The only reliable test for a tube is done with a dynamic tube tester or during actual operation.)

- D. Put equipment and materials away

VACUUM TUBES
UNIT VI

TEST

NAME ________________________ SCORE ________________

1. Match terms associated with vaccum tubes to their correct definitions. Write the correct numbers in the blanks.

_____a. Line relative to the tube's bias drawn across a tube's characteristic curves showing the relationship that voltages and currents will follow for the particular load which the tube is supplying

_____b. Vacuum tube element heated to its burning temperature during tube's manufacturing process

_____c. Electrons emitted from an element when it is bombarded by other electrons

_____d. DC voltage applied to tube's elements to establish operating conditions about which signals and variable input voltages will influence tube's behavior

_____e. Tube that functions with the internal control of an electron beam

_____f. Measure of vacuum tube's resistance to current flow as determined by the tube's voltage divided by current under particular conditions

_____g. Measure of vacuum tube's ability to amplify voltage as determined by the output voltage divided by the input voltage under particular conditions

_____h. Cathode-ray tube used with a computer to display messages, symbols, and computer graphics

_____i. Vacuum tube in which electron ray is directed to a screen where it activates light-emitting material

_____j. Measure of vacuum tube's ability to conduct current as expressed in units of conductance called *mhos*

1. Plate resistance
2. Transconductance
3. Load line
4. Electron tube
5. Visual display unit
6. Bias
7. Secondary emission
8. Amplification factor
9. Cathode-ray tube
10. Getter

TEST

______k. Graph showing the relationship between plate voltage, grid voltage, and plate current for a particular type of vacuum tube at specified conditions

______l. Greek letter (Δ) indicating the change in the value of the quantity to be considered

______m. Pertaining to mathematical laws whereby the addition of two negative numbers results in a sum with a negative sign, and the addition of a negative number and a positive number results in a difference with the sign of the larger number

______n. Mathematical expression that characterizes a device's behavior

______o. One one-millionth of an ampere

______p. One million ohms

______q. Reduction in voltage; usually understood to be due to current flow through a resistance given by Ohm's Law

______r. Relationship between current, resistance, and voltage; expressed mathematically as $E = IR$, $I = \frac{E}{R}$, or $R = \frac{E}{I}$

______s. Method of establishing a grid voltage through the current flow that leaks onto grid from within vacuum tube

______t. Connected through a capacitor, thus isolated from DC while allowing AC signals to be transferred

______u. Specific point at which tube will operate with no input signal

11. Voltage drop
12. Plate characteristic curve
13. Operating point
14. Algebraic
15. Delta
16. Ohm's Law
17. Capacitively coupled
18. Parameter
19. Megohm
20. Microampere
21. Grid leak bias

2. Match abbreviations and symbols associated with vacuum tubes to their correct definitions. Write the correct numbers in the blanks provided.

______a. Capacitor

______b. Transconductance

______c. Cathode-ray tube

______d. Visual display unit

1. C
2. CRT
3. G_m
4. VDU

TEST

______e. Amplification of factor; micro (10^{-6})

______f. Voltage, as in E = IR

______g. Delta; change

______h. Current

______i. Volt

______j. Milli (10^{-3})

______k. Mega (10^{6})

______l. Kilo (10^{3})

______m. Ohm

______n. Resistor

______o. Suppressor grid voltage

______p. Screen grid voltage

______q. Control grid voltage

______r. Plate dynamic resistance

______s. Peak-to-peak

______t. Microampere

5. μ
6. I
7. Δ
8. V
9. μA
10. E
11. K
12. E_{G_1}
13. R_p
14. R
15. M
16. E_{G_2}
17. m
18. Ω
19. E_{G_3}
20. Pk-Pk

3. Match electron tube element symbols to their correct names. Write the correct numbers in the blanks.

______a. Filament

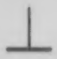
______b. Cathode

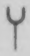
______c. Grid

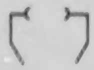
______d. Gas filled

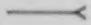
______e. Photo cathode

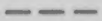
______f. Eye tube deflection

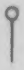
1. 

2. 

3. 

4. 

5. 

6. 

TEST

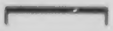
______g. Plate

______h. Cold cathode

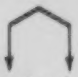
______i. Beam forming plates

7. ●

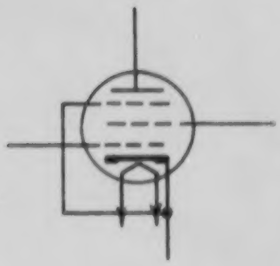
8.

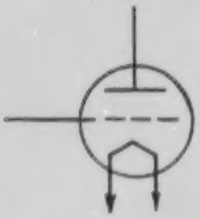


9.



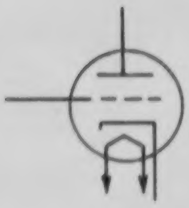
4. Label vacuum tube circuit symbols. Write the correct answers in the blanks below each symbol.

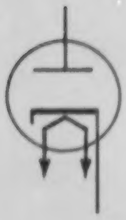




a. ______________________________

b. ______________________________

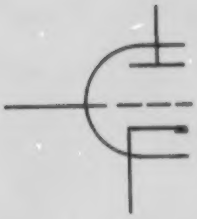


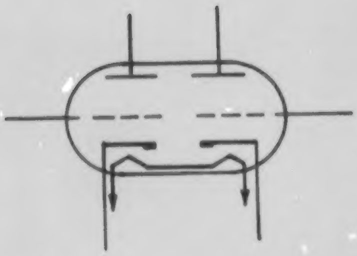


c. ______________________________

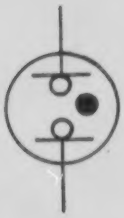
d. ______________________________

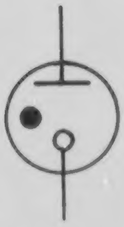
TEST



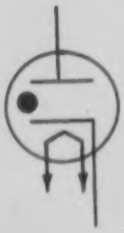


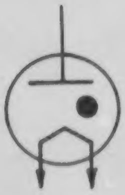
e. ______________________________ f. ______________________________





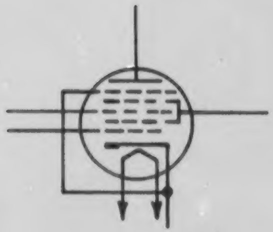
g. ______________________________ h. ______________________________



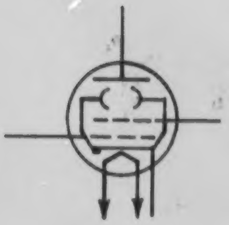


i. ______________________________ j. ______________________________

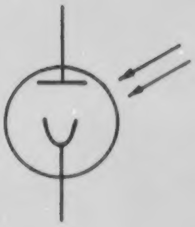
TEST



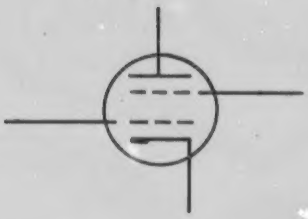
k. ____________________



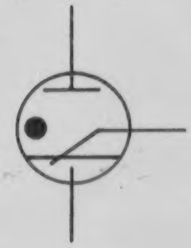
l. ____________________



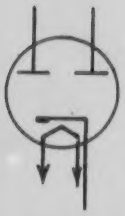
m. ____________________



n. ____________________

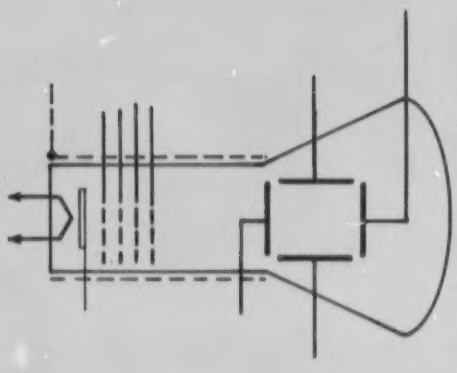


o. ____________________



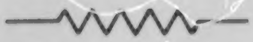
p. ____________________

TEST

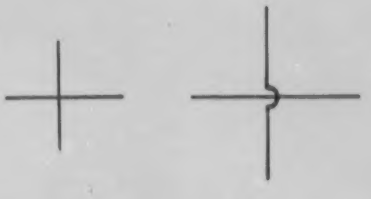


q. ____________________

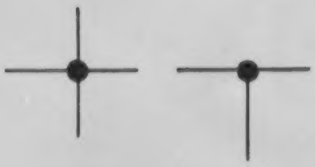
5. Label electronic component circuit symbols. Write the correct answers in the blanks.



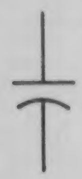
a. ____________________



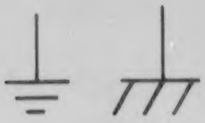
b. ____________________



c. ____________________



d. ____________________



e. ____________________

TEST

6. List elements in a pentode vacuum tube.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

7. List disadvantages of vacuum tubes compared to solid-state devices.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

8. Match vacuum tube primary elements to their correct purposes. Write the correct numbers in the blanks. Purposes are continued on the next page.

_____a. Keeps air from entering vacuum or keeps a particular gas from escaping

_____b. Heats cathode, causing electrons to be released from material

_____c. Supplies electrons from the external circuit into the tube

_____d. Attracts electrons across the gap and returns them to the external circuit

_____e. Causes variations in electron beam so that its voltage is varied

_____f. Improves high frequency operation in reducing capacitance effect between electrodes by dividing gap between them

1. Screen grid
2. Cathode
3. Suppressor grid
4. Envelope or tube
5. Plate or anode
6. Control grid
7. Heater or filament

TEST

______g. Suppresses secondary emission electrons that are driven out of the plate when it is bombarded with the primary beam; grid repells electrons back to plate

9. Select from the folowing list vacuum tube general biasing requirements. Write an "X" in the blank before each correct answer.

______a. Screen grid is always positive compared to the cathode

______b. Control grid is usually a few volts negative, compared to cathode, so that it can vary the flow of passing electrons but not attract a large current

______c. Plate must be more positive than cathode in order to attract electrons

______d. Cathode is usually a few volts negative compared to the control grid so that it can vary the flow of electrons passing through it

______e. Plate must not attract more electrons than does cathode

______f. Cathode must be less positive than plate, even if zero or positive is compared to ground

______g. Suppressor grid is usually connected directly to cathode to suppress secondary emission from plate

10. Determine parameters of vacuum tubes. Use the chart in test question 12 to determine plate current if the grid voltage is -8 V, and the plate voltage is 200 V.

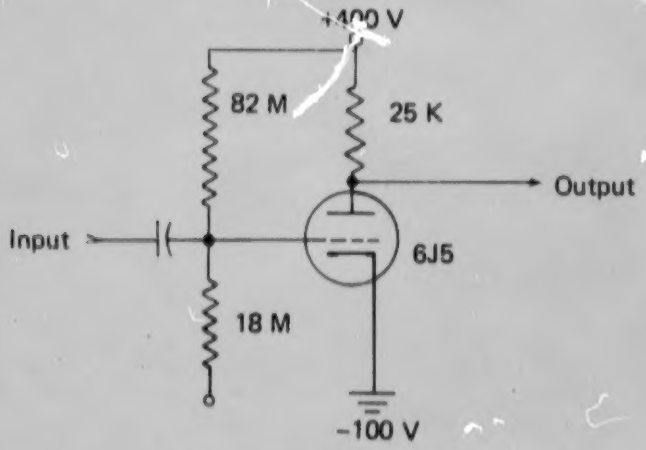
Plate current = ______________________________

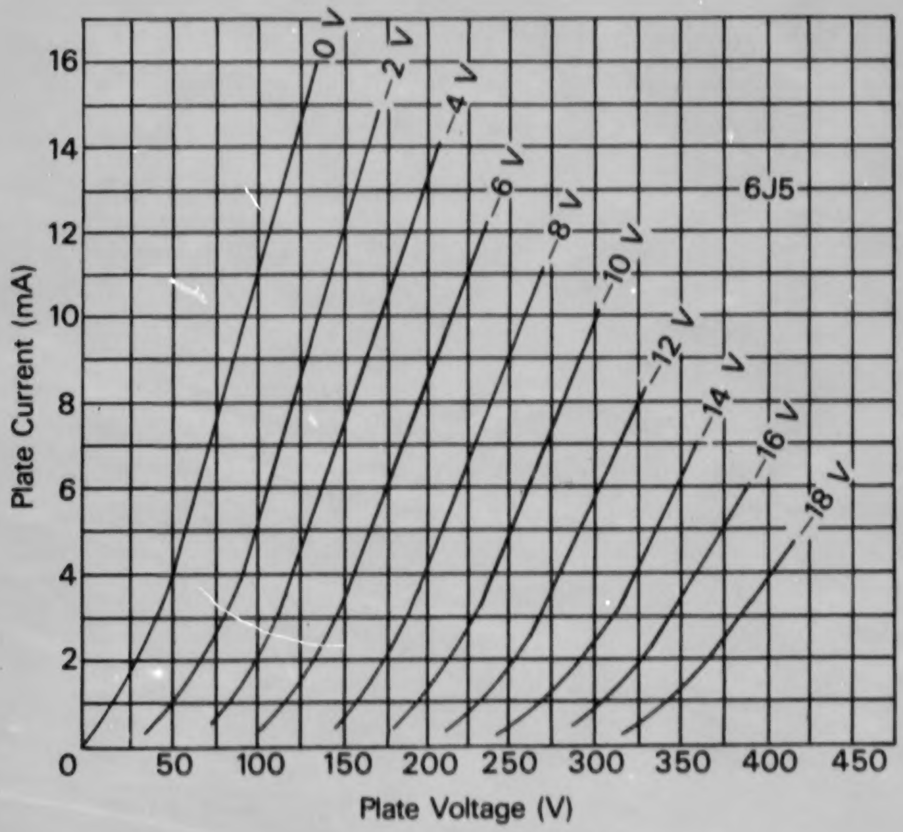
11. Determine vacuum tube plate resistance. Use the plate current found in test question 10, a grid voltage of -8 V, and a plate voltage of 200 V.

R_p = ______________________

TEST

12. Draw a load line on a plate dynamic characteristic curve. Use the circuit and chart below.


+400 V
82 M
25 K
Output
Input
6J5
18 M
-100 V

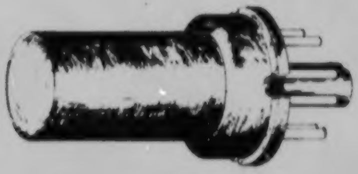


TEST

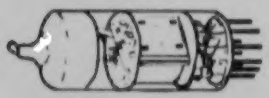
13. Determine the operating point of a simple vacuum tube. Use the circuit and chart in test question 12.

14. Determine the output voltage variation of a vacuum tube circuit. Assume that the circuit has an input voltage of 8 volts, peak-to-peak. Use the chart in test question 12.

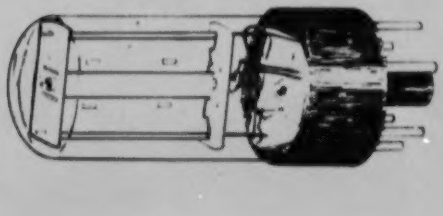
15. Label types of vacuum tubes. Write the correct answers in the blanks below each tube.



a. ______________________________

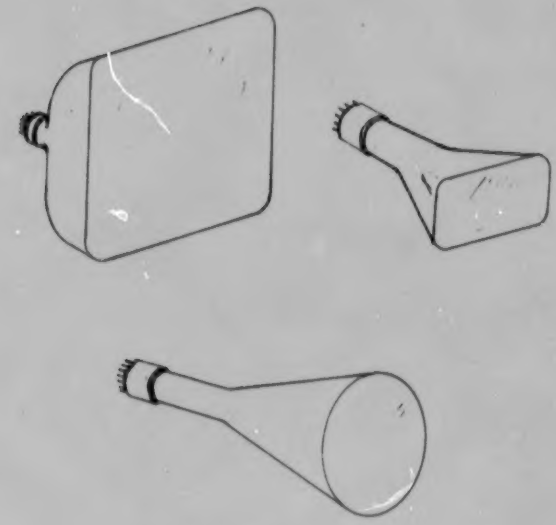


b. ______________________________

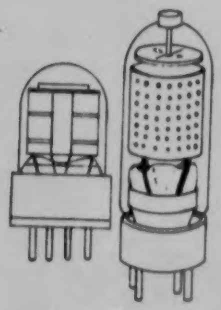


c. ______________________________

TEST

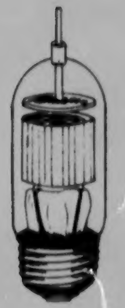


d. ____________________

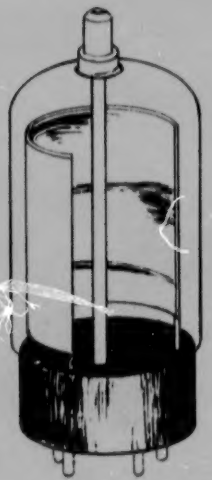


e. ____________________

TEST

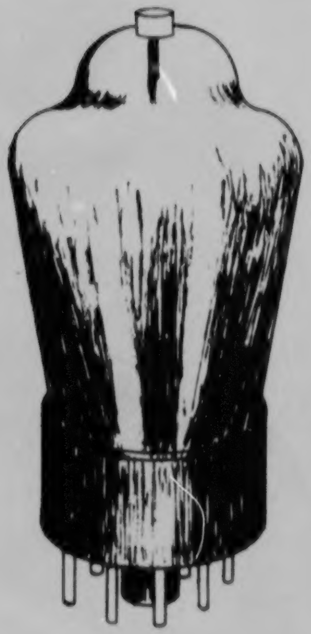


f. ______________________________



g. ______________________________

TEST



h. ____

16. State the mathematical formulas and conditions of principal vacuum tube parameters.

    a. Plate resistance

    Formula = ____________________________________

    b. Amplification factor

    Formula = ____________________________________

    c. Transconductance

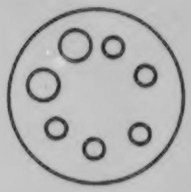
    Formula = ____________________________________

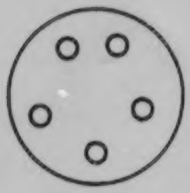
17. State the mathematical formula for finding the relationship between vacuum tube parameters.

    Formula = ____

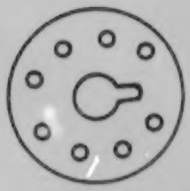
TEST

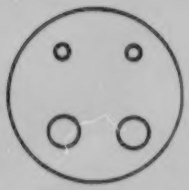
18. Label vacuum tube pins. Write the correct pin numbers on the diagrams below.



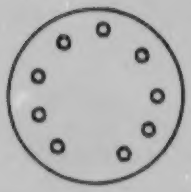


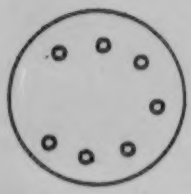
a. ____________________ b. ____________________





c. ____________________ c. ____________________





e. ____________________ f. ____________________

TEST

19. Describe the vacuum tube identification type-code.

20. List four common causes of vacuum tube failure.

    a.

    b.

    c.

    d.

(NOTE: Test questions 21 and 22 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

21. Determine the operating conditions of a vacuum tube circuit.

22. Demonstrate the ability to

    a. Test a vacuum tube using a tube tester.

    b. Check a tube with an ohmmeter.

VACUUM TUBES
UNIT VI

ANSWERS TO TEST

1. a. 3
   b. 10
   c. 7
   d. 6
   e. 4
   f. 1
   g. 8
   h. 5
   i. 9
   j. 2
   k. 12
   l. 15
   m. 14
   n. 18
   o. 20
   p. 19
   q. 11
   r. 16
   s. 21
   t. 17
   u. 13

2. a. 1
   b. 3
   c. 2
   d. 4
   e. 5
   f. 10
   g. 7
   h. 6
   i. 8
   j. 17
   k. 15
   l. 11
   m. 18
   n. 14
   o. 19
   p. 16
   q. 12
   r. 13
   s. 20
   t. 9

3. a. 9
   b. 8
   c. 5
   d. 7
   e. 2
   f. 4
   g. 1
   h. 6
   i. 3

ANSWERS TO TEST

4. a. Pentode
   b. Triode; directly heated cathode
   c. Triode; indirectly heated cathode
   d. Diode; indirectly heated cathode
   e. One-half of a dual triode shown by itself (as in a schematic)
   f. Dual triode
   g. Neon tube; lamp
   h. Gas regulator tube; cold cathode rectifier
   i. Thyratron
   j. Mercury vapor rectifier
   k. Pentagrid
   l. Beam power tube
   m. Photo tube
   n. Tetrode
   o. Ignitron
   p. Dual diode rectifier
   q. Cathode-ray tube

5. a. Resistor
   b. Conductors not connected
   c. Conductors connected
   d. Capacitor
   e. Ground connections

6. a. Plate or anode
   b. Suppressor grid
   c. Screen grid
   d. Control grid
   e. Cathode
   f. Heater or filament
   g. Envelope or tube

ANSWERS TO TEST

7. a. Larger
   b. Produce more heat
   c. Require larger and heavier power supplies
   d. Less energy efficient
   e. Must operate at higher voltages
   f. Must be replaced more often
   g. Require, like most tube-type equipment, more frequent maintenance and calibration

8. a. 4 e. 6
   b. 7 f. 1
   c. 2 g. 3
   d. 5

9. a, b, c, f, g

10. 4 mA

11. 50 K

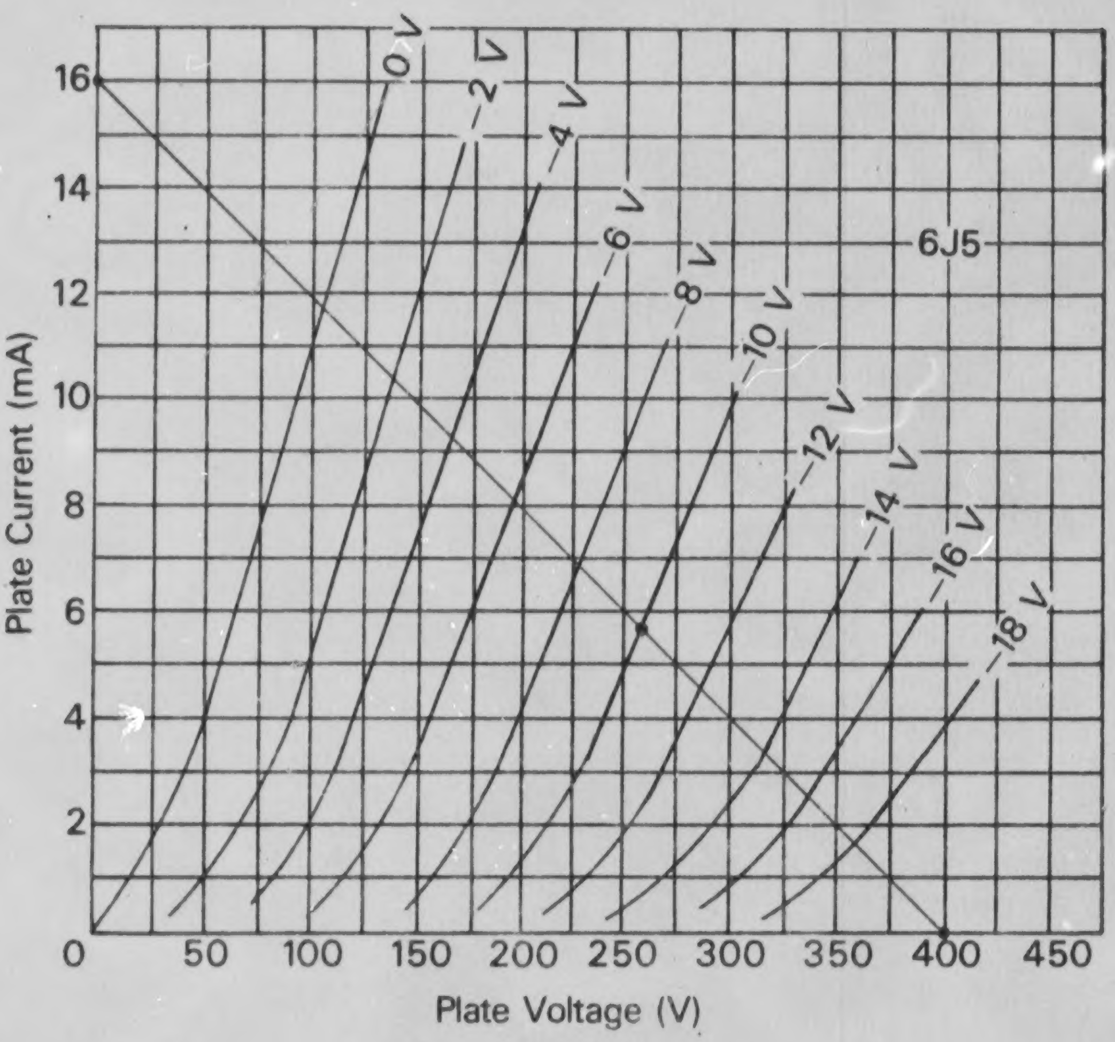
12. See next page

13. See next page

ANSWERS TO TEST

12. (Load line on chart below)

13. (Operating point [dots] on chart below)



ANSWERS TO TEST

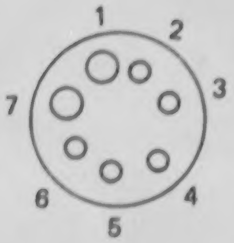
14. 200-315 V; 115 V

15. a. Metal case vacuum tube
    b. Miniature glass vacuum tube
    c. Ordinary vacuum tube
    d. Cathode-ray tube
    e. Thyratron
    f. Mercury vapor rectifier
    g. Photo tube
    h. Beam power tube

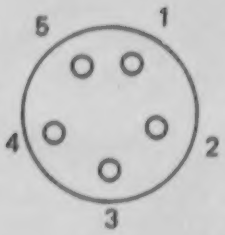
16. a. $R_p = \frac{\Delta E_p}{\Delta I_p}$ --With grid current constant
    b. $\mu = \frac{\Delta E_p}{\Delta E_g}$ --With plate current constant
    c. $G_m = \frac{\Delta I_p}{\Delta E_g}$ --With plate voltage constant

17. $\mu = G_m R_p$

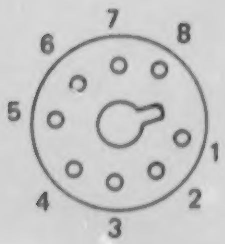
18.



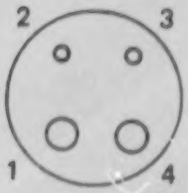
a.



b.

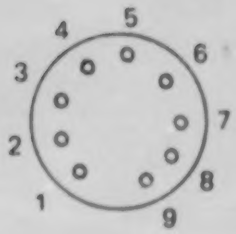


c.

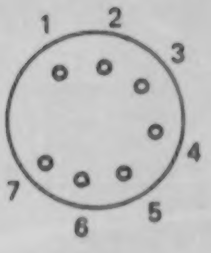


d.

ANSWERS TO TEST



e.



f.

19. Description should include

    a. First number or pair of numbers identifies the filament nominal voltage

    b. Intermediate letters identify the purpose

    c. Second number identifies the number of pins

    d. Suffixes identify special applications and improved versions

20. a. Filament failure

    b. Gassy tube

    c. Shorted elements

    d. Loose elements

21. Evaluated to satisfaction of instructor

22. Performance skills evaluated to satisfaction of instructor

CAPACITANCE AND INDUCTANCE
UNIT VII

UNIT OBJECTIVE

After completing this unit, the student should be able to determine reactance and time constants of capacitors and inductors, and observe the characteristics of alternating current and direct current on capacitors and inductors. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with capacitance and inductance to their correct definitions.
2. Match abbreviations and symbols associated with capacitance and inductance to their correct definitions.
3. Distinguish between uses for capacitors and uses for inductors.
4. Match names of common multipliers to their correct numerical values.
5. Calculate capacitive reactance.
6. Calculate inductive reactance.
7. Calculate charge and discharge time for capacitors and inductors.
8. Discuss categories of time constants.
9. State the effects of frequency on inductors and capacitors.
10. List the effects of capacitance and inductance on the relationship between current and voltage.
11. Name electrical equipment having inductive reactance.
12. Distinguish among alternative names for inductors and capacitors.
13. Select capacitor and inductor circuit symbols.
14. Use the *National Electrical Code* to find information concerning requirements for capacitors.
15. Demonstrate the ability to
    a. Test a capacitor from an alternating current motor.
    b. Observe waveforms of RC and RL circuits.

CAPACITANCE AND INDUCTANCE
UNIT VII

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Introduce students to the *National Electrical Code*, if they are not already familiar with it.

   H. Provide students with a copy of the *National Electrical Code*.

   I. Set up an oscilloscope demonstration to monitor capacitive and inductive lead and lag. Use a dual-trace scope with one trace monitoring the AC supply and the other monitoring a capacitive or inductive circuit. Use "line" as the trigger source. The resulting display should appear as shown in Transparency #4.

   J. Charge a capacitor with a DC power supply, demonstrating the arc that results when it is discharged with a screwdriver. This will illustrate the ability of capacitors to store energy.

   K. Give test.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency masters

      1. TM #1--Universal Time Constant Chart

      2. TM #2--Voltage Waveforms for RC and RL Circuits

      3. TM #3--Capacitor and Inductor Fact Sheet

      4. TM #4--Voltage and Current Waveforms

      5. TM #5--Lead and Lag Relationships

SUGGESTED ACTIVITIES

E. Assignment sheets

1. Assignment Sheet #1--Select Capacitor and Inductor Circuit Symbols
2. Assignment Sheet #2--Calculate Capacitive Reactance
3. Assignment Sheet #3--Calculate Inductive Reactance
4. Assignment Sheet #4--Calculate Capacitor Time Constants
5. Assignment Sheet #5--Calculate Inductor Time Constants
6. Assignment Sheet #6--Use the *National Electrical Code* to Find Information Concerning Requirements For Capacitors

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1--Test a Capacitor From An Alternating Current Motor
2. Job Sheet #2--Observe Waveforms of RC and RL Circuits

H. Test

I. Answers to test

III. Unit references

A. *National Electrical Code*. Boston: National Fire Protection Association, 1980.

B. Seippel, Robert G. *Alternating Current Circuit Analysis*. Chicago: American Technical Society, 1975.

C. Shrader, Robert L. *Electronic Fundamentals for Technicians*. New York: McGraw-Hill, 1972.

D. *Transformers and AC Circuits*. Unit 3, Plant Engineering Training Systems: Electrical Maintenance. Barrington, Illinois: TPC Training Systems, Division of Technical Publishing Co., 1975.

CAPACITANCE AND INDUCTANCE
UNIT VII

INFORMATION SHEET

I. Terms and definitions

   A. Capacitance--Measure of a component's ability to store an electrical charge

   B. Farad--Unit of measurement of capacitance

   C. Inductance--Measure of a component's tendency to oppose any rapid change in current

   D. Henry--Unit of measurement of inductance

   E. Phase--Source of AC power; relationship between time and AC waveform, or between AC waveforms

   F. Tuned circuit--Circuit having dominant frequencies that it reacts to due to individual reactive effects of circuit components

   G. Oscillations--AC waveforms created within a circuit

   H. Filter--Device that reduces rapid variations in voltage or current by restricting variations from the circuit, bypassing variations from the circuit, or slowing rapid variations to gradual changes

   I. Distort--To change the waveform shape through circuit characteristics or interference

   J. Shunt--Parallel path or bypass around a circuit

   K. Tank circuit--Circuit composed of a capacitor and inductor in parallel, which react to form a tuned circuit sensitive to certain frequencies of alternating current

   L. Reactance--Measure of AC resistance offered by components such as capacitors and inductors; measured in units of ohms

   M. Lag or lead angle--Relative displacement between voltage and current waveforms measured in degrees; one cycle is 360 degrees

   N. Time constant--Time required for a capacitor or inductor to charge or discharge to 63%

   O. Kilovar--Unit of 1000 volt-amperes reactive

II. Abbreviations and symbols associated with capacitance and inductance (Assignment Sheet #1)

   A. F--Farads

   B. C--Capacitor, capacitance

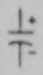
INFORMATION SHEET

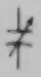
C. H--Henry

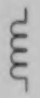
D. L--Inductor; inductance

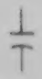
(NOTE: Since "I" is used for current, it would be confusing to also use it for inductance.)

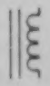
E. π--Greek letter *pi* representing 3.14

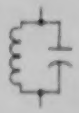
F.  --Circuit symbol for a polar capacitor

G.  --Circuit symbol for a variable capacitor

H.  --Circuit symbol for an air-core inductor

I.  --Circuit symbol for a capacitor

J.  --Circuit symbol for an iron-core inductor

K.  --Circuit symbol for tank circuit

L. f--Frequency

(NOTE : Frequency and farad may be found as "f" or "F," and the manner in which they are used will determine the correct interpretation. Fuses are also denoted by "F.")

M. ϕ--Phase

N. X_C--Capacitive reactance

O. X_L--Inductive reactance

P. Ω--Ohm

909

Q. AC--Alternating current

R. DC--Direct current

S. TC--Time constant

T. t--Time

INFORMATION SHEET

III. Uses for capacitors and uses for inductors

A. Capacitors

1. To block DC power while allowing AC power to be transferred

   EXAMPLE: A capacitor between two stages of an intercom amplifier would keep DC voltages from short circuiting, but would allow the AC voice signals to pass.

   (NOTE: Virtually no current passes through the capacitor; even during AC operation, power is transferred through electrostatic forces.)

2. To give starting boosts to electric motors

   EXAMPLE: Inductive motors often have capacitors connected to their starting circuits to increase starting torque by putting voltage and current in a more effective phase relationship.

3. To correct the power factor of inductive loads

   EXAMPLE: Power companies and many industries connect large capacitors to the power lines to correct the unfavorable effects of motors, transformers, and other inductive loads.

4. To reduce arcing across DC switches, relays, or breaker points

   EXAMPLES: Capacitors connected to DC relays in conjunction with other components constitute what is known as "arc supression"; automotive condensers serve the same purpose.

5. To create tuned circuits

   EXAMPLE: Capacitors are used in conjunction with inductors to create circuits that function at particular selective frequencies for use in industrial control and circuit monitoring.

   (NOTE: Any electric circuit can become "tuned" to certain frequencies, either by design or by chance. Unwanted oscillations can cause equipment malfunctions, create electrical noise, or damage equipment.)

6. To filter direct current

   EXAMPLE: DC power supplies and electrical equipment with built-in power supplies usually have capacitors to filter the DC by reducing instantaneous voltage variations such as *ripple* or *noise*.

INFORMATION SHEET

7. To create particular voltage waveforms

   EXAMPLE: Capacitors can be used in conjunction with other components to distort or reshape voltage waveforms for particular applications.

8. To shunt unwanted electrical noise to ground

   EXAMPLE: Capacitors, and capacitors used with other components, can drain unwanted electrical noise from circuits by offering a low resistance path for those frequencies, but not allowing the circuit operating frequencies to pass.

B. Inductors

1. To resist large, instantaneous surges in current

   EXAMPLE: Inductors placed in circuits to impede surges in currect that could damage equipment or cause malfunctions

2. To filter direct current

   EXAMPLE: Inductors installed in power supplies help to filter voltage by impeding instantaneous current variations

   (NOTE: Inductors used in this manner are often called *chokes*.)

3. To create tuned circuits

   EXAMPLE: Inductors used in conjunction with capacitors to create tuned circuits

   (NOTE: Inductors used in this manner are called *tank circuits*.)

4. To create particular voltage waveforms

   EXAMPLE: Inductors can be used in conjunction with other components to distort or reshape voltage waveforms for particular applications.

IV. Common multipliers and numerical values

A. Giga (G)--10^9 or 1,000,000,000

B. Mega (M)--10^6 or 1,000,000

C. Kilo (K)--10^3 or 1,000

D. Milli (m)--10^{-3} or .001

E. Micro (μ)--10^{-6} or .000,001

F. Nano (n)--10^{-9} or .000,000,001

INFORMATION SHEET

G. Pico (p)--10^{-12} or .000,000,000,001

(NOTE: The abbreviation for micro [μ] is often substituted by the letter "m" or "M" where it is obviously micro and not milli or mega, such as on small capacitors.)

V. Calculating capacitive reactance (Assignment Sheet #2)--Use the formula $X_C = \frac{1}{2\pi fC}$ or $\frac{.159}{fC}$

EXAMPLE 1: A 60 microfarad capacitor is in series with a 60 hertz motor start winding. What is the reactance of the capacitor?

Solution:

$$X_C = \frac{1}{2\pi fC}$$

$$= \frac{1}{(2)\ (3.14)\ (60)\ (60 \times 10^{-6})}$$

$$= 44\ \Omega$$

EXAMPLE 2: A 10 picofarad capacitor is operating in a control circuit at 1,000 hertz. What is the capacitive reactance of the capacitor?

Solution:

$$X_C = \frac{1}{2\pi fC}$$

$$= \frac{1}{(2)\ (3.14)\ (1000)\ (10 \times 10^{-12})}$$

$$= 15{,}900{,}000\ \Omega$$

$$= 15.9\ \mathrm{M}\Omega$$

VI. Calculating inductive reactance (Assignment Sheet #3)--Use the formula $X_L = 2\pi fL$

EXAMPLE 1: A 15 millihenry coil is connected in a 400 hertz circuit. What is the inductive reactance of the coil?

Solution:

$$X_L = 2\pi fL$$

$$= (2)\ (3.14)\ (400)\ (15 \times 10^{-3})$$

$$= 37.7\ \Omega$$

EXAMPLE 2: A 100 microhenry coil is operating in a control circuit at a radio frequency (RF) of 1.5 megahertz. What is its inductive reactance?

Solution:

$$X_L = 2\pi fL$$

$$= (2)\ (3.14)\ (1.5 \times 10^{6})\ (100 \times 10^{6})$$

$$= 942\ \Omega$$

INFORMATION SHEET

VII. Calculating charge and discharge time for capacitors and inductors (Transparencies #1 and #2; Assignment Sheets #4 and #5)

(NOTE: Capicitors and inductors charge and discharge at a rate of about 63% of the voltage difference in each time period equivalent to TC = RC or TC = L/R; thus, a capacitor charged to 100 volts would discharge 63% in the first time period to a residual voltage of 37 volts. Sixty-three percent of the 37 remaining volts would be discharged in the second time period, to a residual voltage of 13.7 volts; 63% of the remaining 13.7 volts would be discharged in the third time period, to leave about 5 volts; and 63% of the remaining 5 volts would be discharged in the fourth time period, to leave about 1.8 volts. In the fifth time period, 63% of the 1.8 volts would be discharged, to leave about 0.7 volts.)

A. For capacitor charge or discharge time calculations, use the formula TC = RC

(NOTE: It takes five time constants for a capacitor or inductor to charge or discharge. 1 second x 5 time constants = 5 seconds for charge or discharge. Therefore, to calculate for complete charge or discharge, use the formula TC = 5RC.)

EXAMPLE: A 100 microfarad capacitor is to be discharged through a circuit that has 10 kilohms of resistance. How much time is required to completely charge the capacitor?

Solution: $TC = 5RC$

$= (5)\ (10\text{ Kohms})\ (100\ \mu F)$

$= (5)\ (10 \times 10^{3})\ (100 \times 10^{-6})$

$= 5$ sec for complete charge

B. For inductor build-up or decay time calculations, use the formula $TC = \frac{L}{R} \times 5$

EXAMPLE: A voltage is applied to a circuit which has a 240 mH inductor in series with a 20 ohm resistor. How much time is required for complete build-up?

Solution: $TC = \frac{L}{R} \times 5$

$= \frac{240\text{ mH}}{20\ \Omega} \times 5$

$= \frac{240 \times 10^{-3}}{20} \times 5$

$= 60$ msec for build-up

INFORMATION SHEET

VIII. Categories of time constants (Transparencies #1 and #2; Assignment Sheets #4 and #5)

(NOTE: Short, medium, and long time constants are determined by a ratio of the time allowed compared to the time required for one time constant. Use the formula $\frac{t}{TC}$)

A. Short time constant--Ratio of 10 or more

EXAMPLE: The time allowed for charge is 10 microseconds, while the TC is 1 microsecond

$$\frac{t}{TC} = \frac{10\ \mu\text{sec}}{1\ \mu\text{sec}}$$

$$= \frac{10 \times 10^{-6}}{1 \times 10^{-6}}$$

$$= 10 \text{ (Ratio)}$$

(NOTE: The time allowed is 10 times greater than the time constant. The time constant is therefore considered to be *short* compared to the time allowed.)

B. Long time constant--Ratio of .1 or less

EXAMPLE: The time allowed for charge is 100 milliseconds while the TC is 1 second

$$\frac{t}{TC} = \frac{100\text{ msec}}{1\text{ sec}}$$

$$= \frac{100 \times 10^{-3}}{1}$$

$$= .1 \text{ (Ratio)}$$

(NOTE: The time constant is 10 times greater than the time allowed. The time constant is therefore considered to be *long* compared to the time allowed.)

C. Medium time constant--Ratio somewhere between that of the short and the long time constant; ratio of between .1 and 10

IX. Effects of frequency on inductors and capacitors (Transparency #3)

A. Reactance of inductors increases as frequency increases

B. Reactance of inductors decreases as frequency decreases

(NOTE: To help remember this effect, merely look at the formula, $X_L = 2\pi fL$, to see that when "f" increases so does "X_L." Thus, inductors offer more resistance to high frequencies.)

C. Reactance of capacitors decreases as frequency increases

INFORMATION SHEET

D. Reactance of capacitors increases as frequency decreases

(NOTE: To help remember this effect, merely look at the formula

$$X_C = \frac{1}{2\pi fC}$$

to see that when "f" increases, the fraction becomes smaller and "X_C" decreases. Thus, capacitors offer little resistance to high frequencies.)

X. Effects of capacitance and inductance on the relationship between current and voltage (Transparencies #4 and #5)

A. Capacitance--Causes voltage to lag behind current by 90°

B. Inductance--Causes current to lag behind voltage by 90°

(NOTE: The 90° angle is for ideal or "pure" components with no direct current resistance characteristics. Actual components will have less than a 90° phase shift.)

XI. Electrical equipment having inductive reactance

A. Transformers

B. Solenoid and relay coils

C. Electric motors

D. Lengthy power lines

E. Fluorescent light ballasts

(NOTE: Inductance is a result of coils or winding; hence, any such equipment will produce inductance.)

XII. Alternative names for inductors and capacitors

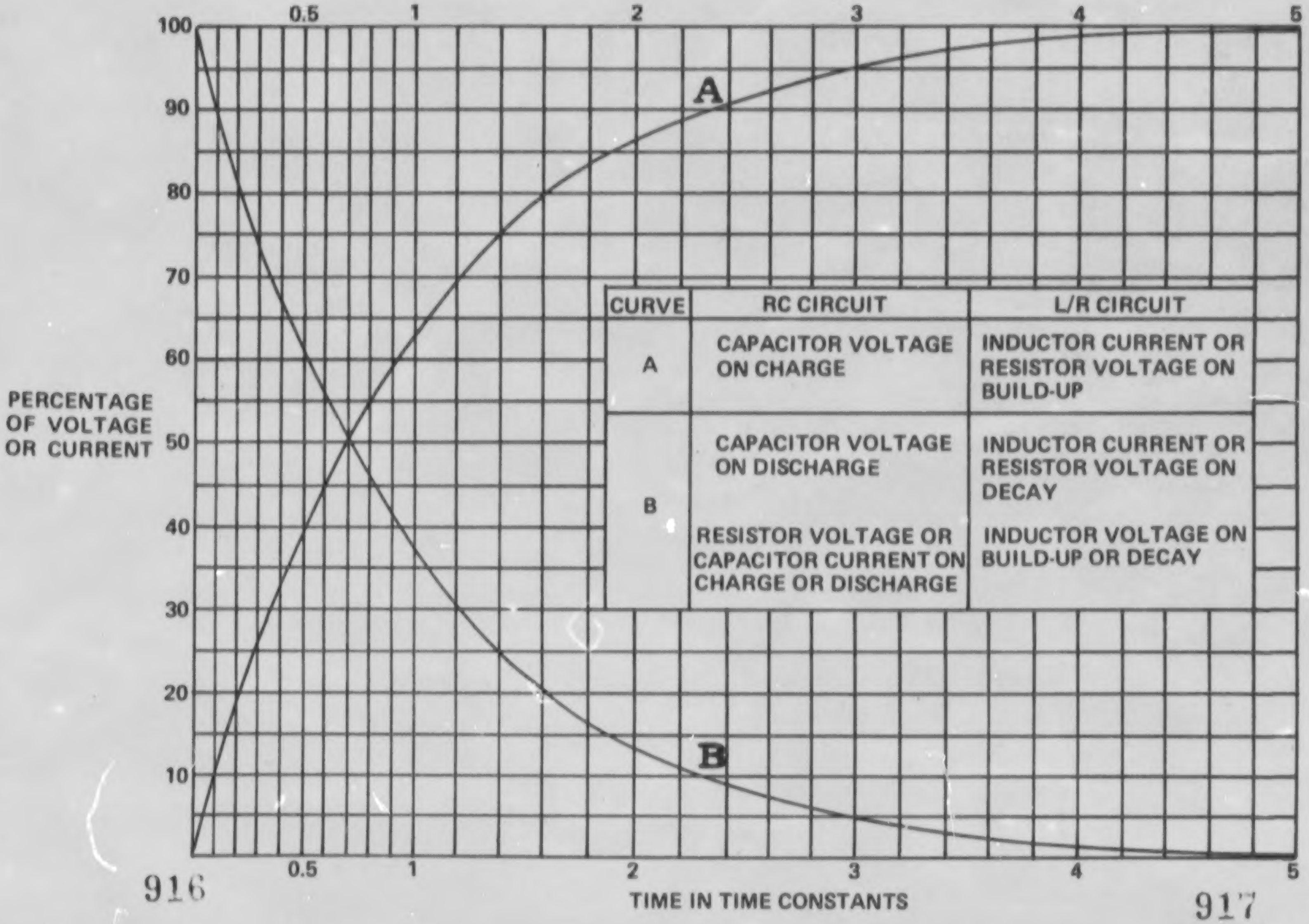
A. Inductors

1. Choke
2. Coil
3. Reactor
4. Filter choke
5. Smoothing coil

B. Capacitors

1. Cap
2. Condenser
3. Surge capacitors

Universal Time Constant Chart

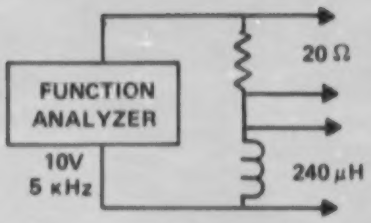


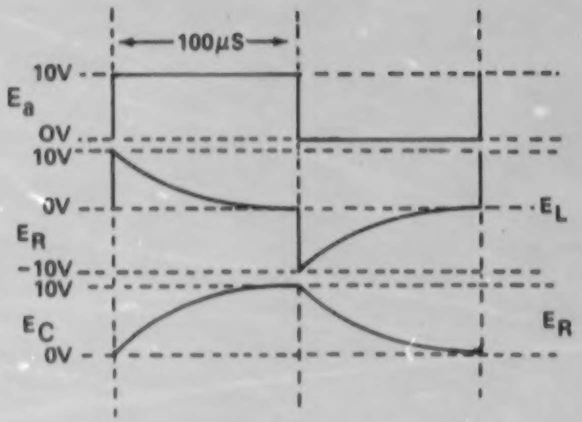
CURVE	RC CIRCUIT	L/R CIRCUIT
A	CAPACITOR VOLTAGE ON CHARGE	INDUCTOR CURRENT OR RESISTOR VOLTAGE ON BUILD-UP
B	CAPACITOR VOLTAGE ON DISCHARGE	INDUCTOR CURRENT OR RESISTOR VOLTAGE ON DECAY
	RESISTOR VOLTAGE OR CAPACITOR CURRENT ON CHARGE OR DISCHARGE	INDUCTOR VOLTAGE ON BUILD-UP OR DECAY

TM #1

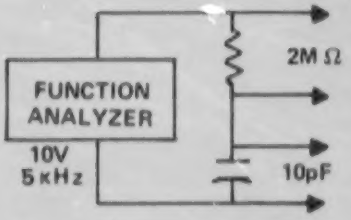
IIEE - 395-E

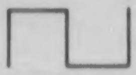
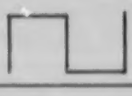
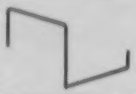
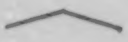
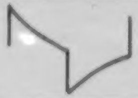
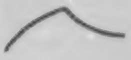
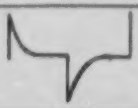
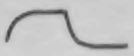
Voltage Waveforms For RC and RL Circuits


FUNCTION ANALYZER
10V
5 kHz
20 Ω
240 μH



MEDIUM TIME CONSTANT


FUNCTION ANALYZER
10V
5 kHz
2M Ω
10pF

	OUTPUT A E_R – RC CIRCUIT E_L – RL CIRCUIT	OUTPUT B E_C – RC CIRCUIT E_R – RL CIRCUIT
INPUT WAVE		
LONG TIME CONSTANT		
MEDIUM TIME CONSTANT		
SHORT TIME CONSTANT		

Capacitor and Inductor Fact Sheet

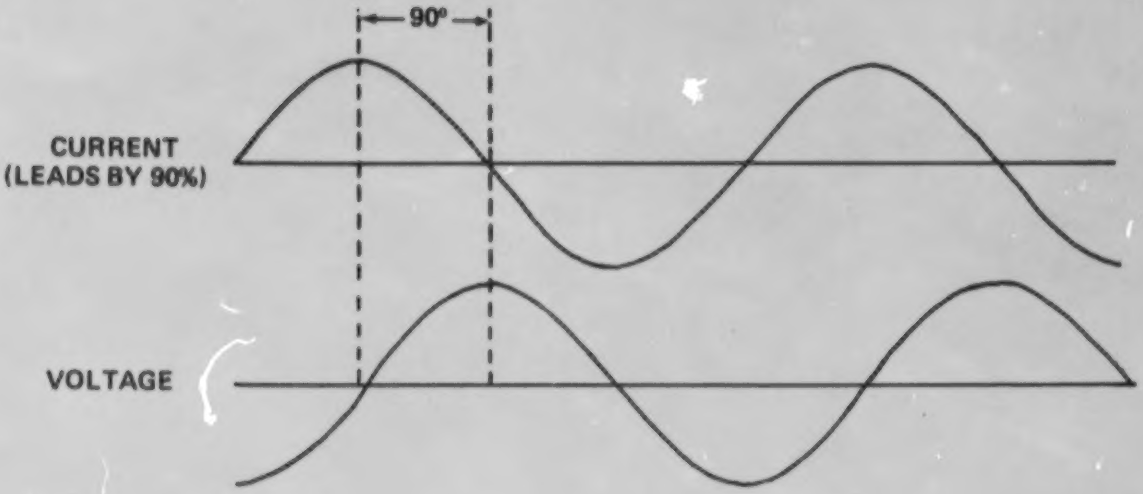
	CAPACITORS	INDUCTORS
1. RESISTANCE TO DIRECT CURRENT	INFINITE (Block DC)	VERY LOW (Readily Pass DC)
2. RESISTANCE TO HIGH FREQUENCY AC	VERY LOW (Readily Pass AC)	VERY HIGH (Restrict AC)
3. FORMULA FOR REACTANCE	$X_C = \frac{1}{2 \pi fC}$	$X_L = 2 \pi fL$
4. SIMPLIFIED FORMULA FOR 60 HERTZ	$X_C = \frac{1}{377C}$	$X_L = 377L$
5. LETTER DESIGNATOR FOR SCHEMATICS AND FORMULA	C	L
6. AFFECT IN AC CIRCUITS ON VOLTAGE AND CURRENT	CURRENT LEADS VOLTAGE (ICE)	VOLTAGE LEADS CURRENT (ELI)
7. MOST COMMON RANGE OF VALUES	MICROFARADS (μF)	MILLIHENRIES (mH)

TM #3

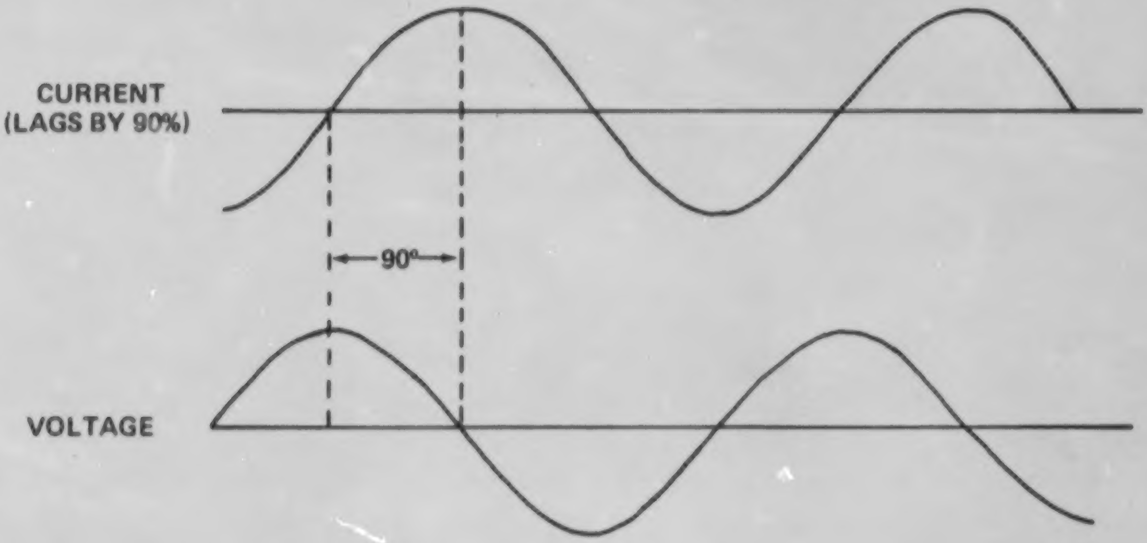
IIEE - 399-E

Voltage and Current Waveforms

Capacitive Circuit Waveforms


90°
CURRENT
(LEADS BY 90%)
VOLTAGE

Inductive Circuit Waveforms


CURRENT
(LAGS BY 90%)
90°
VOLTAGE

IIEE - 403-E

Lead and Lag Relationships

E L I THE I C E MAN

VOLTAGE ... IN AN INDUCTIVE CIRCUIT ... IS AHEAD OF CURRENT

CURRENT ... IN A CAPACITIVE CIRCUIT... IS AHEAD OF VOLTAGE

TM #5

CAPACITANCE AND INDUCTANCE
UNIT VII

ASSIGNMENT SHEET #1--SELECT CAPACITOR AND INDUCTOR CIRCUIT SYMBOLS

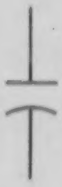
NAME ______________________________ SCORE ____________

Technicians and electricians must learn to recognize circuit symbols correctly to be able to construct circuits, read technical material, understand schematics and wiring diagrams, and troubleshoot circuits.

Of the following symbols (Figures 1-20), select only those that are symbols for capacitors and inductors. Write *CAP* for capacitors and *IND* for inductors.

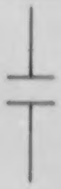
(NOTE: Do not confuse capacitor symbols with symbols for relay contacts and single-cell batteries; and do not confuse inductor symbols with symbols for transformers and relay coils.)

FIGURE 1



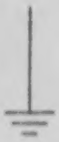
A. ______________________

FIGURE 2



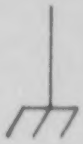
B. ______________________

FIGURE 3



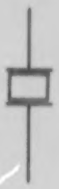
C. ______________________

FIGURE 4



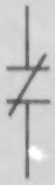
D. ______________________

FIGURE 5



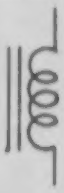
E. ______________________

FIGURE 6



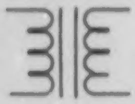
F. ______________________

FIGURE 7



G. ______________________

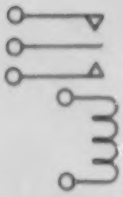
FIGURE 8



H. ______________________

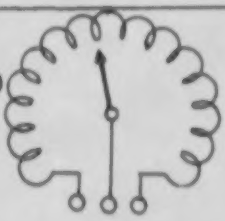
ASSIGNMENT SHEET #1

FIGURE 9



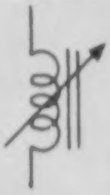
I. ____________________

FIGURE 10



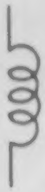
J. ____________________

FIGURE 11



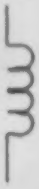
K. ____________________

FIGURE 12



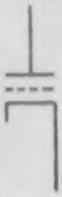
L. ____________________

FIGURE 13



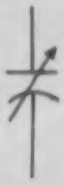
M. ____________________

FIGURE 14



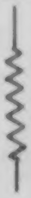
N. ____________________

FIGURE 15



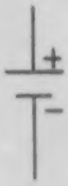
O. ____________________

FIGURE 16



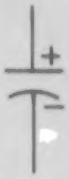
P. ____________________

FIGURE 17



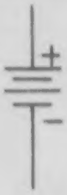
Q. ____________________

FIGURE 18



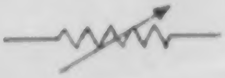
R. ____________________

FIGURE 19



S. ____________________

FIGURE 20



T. ____________________

CAPACITANCE AND INDUCTANCE
UNIT VII

ASSIGNMENT SHEET #2--CALCULATE CAPACITIVE REACTANCE

NAME ______________________________ SCORE ______________

Capacitive reactance must be calculated to correct poor power factor characteristics of motor circuits, and technicians must calculate reactance to determine loading effects on circuits.

Calculate the reactance of the capacitors below.

A. A manufacturer produces 100 microfarad capacitors for motor circuits and large power supplies. What is the capacitive reactance of the capacitors at 60 hertz?

X_C = ______________________

B. If the capacitors are sold to a plant in Germany where the power is 50 hertz, what will be the reactance of the capacitors?

X_C = ______________________

CAPACITANCE AND INDUCTANCE
UNIT VII

ASSIGNMENT SHEET #3--CALCULATE INDUCTIVE REACTANCE

NAME ______________________________ SCORE ______________

Capacitive reactance and inductive reactance cancel each other. For this reason, capacitors are installed on inductive motor circuits.

Calculate the inductive reactance of the following inductors.

A. A 60-hertz motor has been found to have 10 millihenries of inductance when the rotor is locked. What is the motor's inductive reactance under this condition?

X_L = ______________________________

B. A transformer has .2 henries of inductance when the secondary side is not connected. What is the inductive reactance of the transformer when operated at 400 hertz with the secondary disconnected?

X_L = ______________________________

C. A 5 millihenry choke is operating at 10,000 hertz. What is the choke's inductive reactance?

X_L = ______________________________

CAPACITANCE AND INDUCTANCE
UNIT VII

ASSIGNMENT SHEET #4--CALCULATE CAPACITOR TIME CONSTANTS

NAME ______________________________ SCORE ______________

A capacitor charges or discharges in approximately 5 time constants (TC = 5RC).

Use this approximation to calculate the charge or discharge times of the capacitors in the following problems.

A. A large capacitor is to be discharged through a 1,000 ohm resistor. The capacitor is 150 microfarads. How much time is required to discharge the capacitor?

______________________________ sec

B. A 200 microfarad capacitor is operating with a 100 ohm resistor in series.

1. What is the time required for the capacitor to charge?

   ______________________________ sec

2. What is the time required for the capacitor to discharge?

   ______________________________ sec

3. If the voltage was shut off every .2 of a second and the capacitor was allowed to discharge every .2 of a second, would the capacitor ever reach the fully charged value?

   ____

4. Would the capacitor described in #3 ever reach the fully discharged value?

   ____

CAPACITANCE AND INDUCTANCE
UNIT VII

ASSIGNMENT SHEET #5--CALCULATE INDUCTOR TIME CONSTANTS

NAME ________________________________ SCORE ______________

Inductor build-up or decay occurs in approximately 5 time constants. Use this approximation to calculate the build-up or decay time for the inductors in the problems below. Use the formula $TC = \frac{L}{R} \times 5$

A 1 henry inductor is used in a circuit with a 5-Kohm resistor using a 60-hertz signal.

A. How much time is required for the inductor to build-up?

________________________________ msec

B. How much time is required for the inductor to decay?

________________________________ msec

C. What would be the time for one cycle with the frequency listed above?

________________________________ msec

D. Would this signal be a short, medium, or long time constant?

____

CAPACITANCE AND INDUCTANCE
UNIT VII

ASSIGNMENT SHEET #6--USE THE *NATIONAL ELECTRICAL CODE* TO FIND INFORMATION CONCERNING REQUIREMENTS FOR CAPACITORS

NAME ______________________________ SCORE __________

The *National Electrical Code* specifies how electrical circuitry should be installed and maintained for safety. Small capacitors used in electronic equipment and within enclosures are primarily the concern of the electronics industry and other regulatory agencies. Large capacitors are employed by industry to get more efficient use from AC power, to operate power converters that change AC to DC, and for various particular applications. Use the *NEC* to answer the following questions related to the section about capacitors.

A. What is the maximum time a capacitor may be allowed to discharge to 50 volts or less after being disconnected from the power?

____

B. Should capacitors be connected to an overcurrent device? __________

C. What specific information is required on a capacitor nameplate?

____

____

____

____

____

____

____

D. If a capacitor is installed to operate over 600 volts, would it be possible to visually check to see if it is disconnected when it is switched out of service?

____

E. Which article specifies capacitor requirements?

____

F. Which article specifies the grounding of capacitor cases?

____

CAPACITANCE AND INDUCTANCE
UNIT VII

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

(NOTE: Answers in parentheses were not required.)

A. CAP
B. CAP
C. (Earth ground)
D. (Chassis ground)
E. (Crystal)
F. (Relay contact)
G. IND
H. (Transformer)
I. (Relay coil)
J. (Transformer)
K. IND
L. IND
M. IND
N. (Vacuum tube)
O. CAP
P. (Resistor)
Q. (Battery cell)
R. CAP
S. (Battery)
T. (Resistor)

Assignment Sheet #2

A. 26.5 Ω
B. 31.8 Ω

Assignment Sheet #3

A. 3.77 Ω
B. 502 Ω
C. 314 Ω

Assignent Sheet #4

A. 0.75 sec
B. 1. 0.1 sec
   2. 0.1 sec
   3. Yes
   4. Yes

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #5

A. 1 msec

B. 1 msec

C. 16.7 msec

D. Short (41.5)

Assignment Sheet #6

A. 1 min or 60 sec

B. Yes

C. Name of manufacturer; rated voltage; frequency; kilovar or amperes; number of phases; number of gallons of flammable liquid, or statement that no flammable liquid is contained; whether it is equipped with an internal discharge device

D. Yes

E. Article 460

F. Article 250

CAPACITANCE AND INDUCTANCE
UNIT VII

JOB SHEET #1--TEST A CAPACITOR FROM AN ALTERNATING CURRENT MOTOR

I. Equipment and materials

A. AC motor--Capacitor-type

B. Screwdrivers or nutdrivers--As required to remove the capacitor cover from the motor

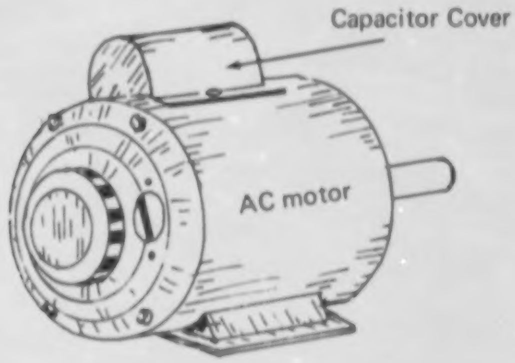
C. Capacitor tester--Suitable for testing motor starting-capacitors

II. Procedure

A. Remove the capacitor cover

(NOTE: It is a metal enclosure on the outside of the motor as shown in Figure 21. It may be cylindrical or box-shaped and on the top or either side of the motor.)

FIGURE 21



B. Once capacitor terminals are exposed, place the shank of the screwdriver across terminals to discharge any stored power that may have remained in the capacitor

(CAUTION: Capacitors may store enough power to cause injury or death due to electrical shock. Small or low charged capacitors can result in serious injury due to involuntary muscle reactions that result when even small electrical shocks are felt. For these reasons, capacitors should be discharged prior to working with them. Large capacitors should not be discharged directly, but should be discharged through a resistance.)

JOB SHEET #1

C. Jot down which terminals of the capacitor are connected to which wires

(NOTE: While it is often of no consequence, a technician should always reconnect circuits exactly as they were previously, unless the connections are known to be arbitrary or in error.)

D. Disconnect capacitor

E. Remove capacitor from motor

F. Inspect the capacitor visually for defects

(NOTE: Look for a ruptured case, oil leaking from the case, loose or broken terminals, or signs of overheating such as discolored or burned surfaces.)

G. Test capacitor with capacitor tester

H. Compare the tested value with the value printed on the case of the capacitor

I. Record the values

Value as shown on capacitor case-- ________________________________

Value as indicated by capacitor tester-- ______ __________________________

(NOTE: Show your test results to the instructor.)

J. Replace capacitor if it appears and tests to be in good condition

K. Replace capacitor cover, fastening the screws

(NOTE: Have your instructor inspect your work.)

L. Put equipment and materials away

CAPACITANCE AND INDUCTANCE
UNIT VII

JOB SHEET #2--OBSERVE WAVEFORMS OF RC AND RL CIRCUITS

I. Equipment and materials

   A. Dual-trace oscilloscope

   B. Function generator

   C. Frequency counter

   D. Oscilloscope probes--2

   E. Resistor--20 Ω

   F. Capacitor--10 μF

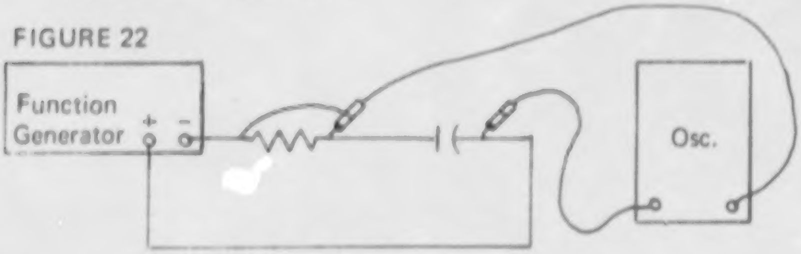
   G. Inductor--10 mH

   H. Test leads

II. Procedure

   A. Connect the function generator, the resistor, and the capacitor in series as shown in Figure 22

FIGURE 22



   B. Adjust output of the function generator to 100 Hz and maximum amplitude

   (NOTE: Frequency can be measured by using the frequency counter.)

   C. Connect oscilloscope to the circuit

   D. Hook Channel A across the capacitor and Channel B across the resistor

   E. Observe the waveforms

   F. Determine whether this is a short, medium, or long time constant, and indicate below

   Measured = ________________ Calculated = ________________

JOB SHEET #2

G. Change the frequency of the function generator to 1 kHz

H. Repeat steps E and F and indicate results below

Measured = ____________________ Calculated = ____________________

I. Change the frequency of the function generator to 100 kHz

J. Repeat steps E and F and indicate results below

Measured = ____________________ Calculated = ____________________

K. Remove capacitor from circuit

L. Replace with the 10 mH inductor

M. Adjust output of the function generator to 100 Hz

N. Connect oscilloscope to the circuit

O. Hook Channel A across the inductor and Channel B across the resistor

P. Observe the waveforms

Q. Determine whether this is a short, medium, or long time constant, and indicate below

Measured = ____________________ Calculated = ____________________

R. Change the frequency of the function generator to 1 kHz

S. Repeat steps P and Q and indicate results below

Measured = ____________________ Calculated = ____________________

T. Change the frequency of the function generator to 100 kHz

U. Repeat steps P and Q and indicate results below

Measured = ____________________ Calculated = ____________________

V. Turn off the equipment

(NOTE: Discuss your answers with your instructor.)

W. Put equipment and materials away

CAPACITANCE AND INDUCTANCE
UNIT VII

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with capacitance and inductance to their correct definitions. Write the correct numbers in the blanks. Definitions are continued on the next page.

_____a. Circuit having dominant frequencies that it reacts to due to individual reactive effects of circuit components

_____b. Unit of measurement of inductance

_____c. Measure of a component's ability to store an electrical charge

_____d. Unit of measurement of capacitance

_____e. Source of AC power; relationship between time and AC waveform, or between AC waveforms

_____f. Measure of a component's tendency to oppose any rapid change in current

_____g. Parallel path or bypass around a circuit

_____h. Circuit composed of a capacitor and inductor in parallel, which react to form a tuned circuit sensitive to certain frequences of alternating current

_____i. To change the waveform shape through circuit characteristics or interference

_____j. AC waveforms created within a circuit

_____k. Device that reduces rapid variations in voltage or current by restricting variations from the circuit, bypassing variations from the circuit, or slowing rapid variations to gradual changes

_____l. Measure of AC resistance offered by components such as capacitors and inductors; measured in units of ohms

_____m. Time required for a capacitor or inductor to charge or discharge to 63%

1. Capacitance
2. Farad
3. Inductance
4. Henry
5. Phase
6. Tuned circuit
7. Oscillations
8. Filter
9. Distort
10. Shunt
11. Tank circuit
12. Reactance
13. Lag or lead angle
14. Time constant
15. Kilovar

TEST

____n. Relative displacement between voltage and current waveforms measured in degrees; one cycle is 360 degrees

____o. Unit of 1000 volt-amperes reactive

2. Match abbreviations and symbols associated with capacitance and inductance to their correct definitions. Write the correct numbers in the blanks.

____a. Circuit symbol for a capacitor

____b. Farads

____c. Capacitor; capacitance

____d. Inductor; inductance

____e. Henry

____f. Inductive reactance

____g. Circuit symbol for an air-core inductor

____h. Circuit symbol for a variable capacitor

____i. Circuit symbol for a polar capacitor

____j. Capacitive reactance

____k. Greek letter *pi* representing 3.14

____l. Phase

____m. Circuit symbol for an iron-core inductor

____n. Frequency

____o. Circuit symbol for tank circuit

____p. Ohm

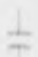
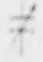
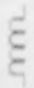
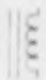
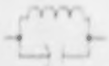
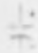
____q. Alternating current

____r. Direct current

____s. Time constant

____t. Time

937

1. F
2. C
3. H
4. L
5. AC
6. TC
7. Ω
8. π
9. DC
10. ϕ
11. X_L
12. X_C
13. f
14. t
15. 
16. 
17. 
18. 
19. 
20. 

TEST

3. Distinguish between uses for capacitors and uses for inductors. Write a "C" for capacitors and an "I" for inductors. A blank may have more than one correct answer.

______a. To restrict large, instantaneous surges in current

______b. To block DC power while allowing AC power to be transferred

______c. To filter direct current

______d. To give starting boosts to electric motors

______e. To create tuned circuits

______f. To correct the power factor of inductive loads

______g. To reduce arcing across DC switches, relays, or breaker points

______h. To create particular voltage waveforms

______i. To shunt unwanted electrical noise to ground

4. Match names of common multipliers to their correct numerical values. Write the correct numbers in the blanks.

______a. 10^{-3} or .001
______b. 10^{-12} or .000,000,000,001
______c. 10^{9} or 1,000,000,000
______d. 10^{3} or 1,000
______e. 10^{-9} or .000,000,001
______f. 10^{6} or 1,000,000
______g. 10^{-6} or .000,001

1. Giga (G)
2. Mega (M)
3. Kilo (K)
4. Milli (m)
5. Micro (μ)
6. Nano (n)
7. Pico (p)

5. Calculate capacitive reactance in the problem below.

A capacitor bank in an industrial plant has four capacitors in parallel for a total capacitance of 200 microfarad or .2 millifarad. What is the capacitive reactance at 60 hertz? Use the formula $X_C = \frac{1}{2\pi f C}$.

X_C = ____________________________________

TEST

6. Calculate inductive reactance in the problem below. Use the formula $X_L = 2\pi fL$.

A large electromagnet used in a steel mill has an inductance of 100 millihenries. What is its inductive reactance at 60 hertz?

X_L = ______________________________

7. Calculate charge and discharge time for capacitors and inductors in the problem below. Use the formula TC = 5RC.

A large industrial motor starting capacitor is 400 microfarads and discharges through a 50,000 ohm resistance when the motor is turned off. Approximately how much time will be required for the capacitor to discharge?

TC = ______________________________

8. Discuss categories of time constants.

____

____

____

____

9. State the effects of frequency on inductors and capacitors.

a. ____

b. ____

c. ____

d. ____

TEST

10. List the effects of capacitance and inductance on the relationship between current and voltage.

    a. Capacitance-- ____

    ____

    b. Inductance-- ____

    ____

11. Name electrical equipment having inductive reactance.

    a. ____

    b. ____

    c. ____

    d. ____

    e. ____

12. Distinguish among alternative names for inductors and capacitors. Write an "I" for inductors and a "C" for capacitors.

    ______a. Choke

    ______b. Coil

    ______c. Cap

    ______d. Reactor

    ______e. Condenser

    ______f. Filter choke

    ______g. Smoothing coil

    ______h. Surge capacitors

(NOTE: Test questions 13-15 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

13. Select capacitor and inductor circuit symbols.

14. Use the *National Electrical Code* to find information concerning requirements for capacitors.

15. Demonstrate the ability to

    a. Test a capacitor from an alternating current motor.

    b. Observe waveforms of RC and RL circuits.

CAPACITANCE AND INDUCTANCE
UNIT VII

ANSWERS TO TEST

1. a. 6
b. 4
c. 1
d. 2
e. 5
f. 3
g. 10
h. 11
i. 9
j. 7
k. 8
l. 12
m. 14
n. 13
o. 15

2. a. 15
b. 1, 13
c. 2
d. 4
e. 3
f. 11
g. 17
h. 16
i. 20
j. 12
k. 8
l. 10
m. 18
n. 13, 1
o. 19
p. 7
q. 5
r. 9
s. 6
t. 14

3. a. I
b. C
c. I, C
d. C
e. I, C
f. C
g. C
h. C, I
i. C

4. a. 4
b. 7
c. 1
d. 3
e. 6
f. 2
g. 5

ANSWERS TO TEST

5. 13.3 Ω
6. 37.6 Ω
7. 100 sec
8. Discussion should include
   a. Short time constant - Ratio of 10 or more
   b. Medium time constant--Ratio somewhere between that of the short and the long time constant; ratio of between .1 and 10
   c. Long time constant - Ratio of .1 or less
9. a. Reactance of inductors increases as frequency increases
   b. Reactance of inductors decreases as frequency decreases
   c. Reactance of capacitors decreases as frequency increases
   d. Reactance of capacitors increases as frequency decreases
10. a. Capacitance--Causes voltage to lag behind the current by 90°
   b. Inductance--Causes current to lag behind the voltage by 90°
11. a. Transformers
   b. Solenoid and relay coils
   c. Electric motors
   d. Lengthy power lines
   e. Fluorescent light ballasts
12. a. I
   b. I
   c. C
   d. I
   e. C
   f. I
   g. I
   h. C
13. Evaluated to satisfaction of instructor
14. Evaluated to satisfaction of instructor
15. Performance skills evaluated to satisfaction of instructor

RC AND RL CIRCUITS
UNIT VIII

UNIT OBJECTIVE

After completing this unit, the student should be able to determine impedance, voltage, current, and power of series and parallel RC and RL circuits, and observe their phase relationships. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with RC and RL circuits to their correct definitions.
2. Match abbreviations associated with RC and RL circuits to their correct definitions.
3. Label symbols associated with RC and RL circuits.
4. State the Pythagorean Theorem as it applies to vectors.
5. Select from a list correct statements about the relationship of parts of right triangles to electric vectors.
6. Draw a vector diagram of the phase relationship between resistance, capacitance, and inductance.
7. Calculate impedance of a series RC circuit.
8. Calculate current of a series RC or RL circuit.
9. Calculate the phase angle of a series RC or RL circuit.
10. Calculate voltage in a series RC circuit.
11. Calculate the applied voltage of a series RC or RL circuit.
12. Calculate impedance of a series RL circuit.
13. Calculate voltage in a series RL circuit.
14. Calculate power of a series RC or RL circuit.
15. Calculate current of a parallel RC circuit.
16. Calculate impedance of a parallel RC circuit.
17. Calculate the phase angle of a parallel RC circuit.

OBJECTIVE SHEET

18. Calculate power of a parallel RC or RL circuit.
19. Calculate current of a parallel RL circuit.
20. Calculate impedance of a parallel RL circuit.
21. Calculate the phase angle of a parallel RL circuit.
22. Calculate parameters and draw vectors of a series RC circuit.
23. Calculate parameters and draw vectors of a series RL circuit.
24. Calculate parameters and draw vectors of a parallel RC circuit.
25. Calculate parameters and draw vectors of a parallel RL circuit.
26. Demonstrate the ability to
    a. Determine the phase difference in a series RC circuit.
    b. Determine the phase difference in a series RL circuit.

RC AND RL CIRCUITS
UNIT VIII

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Show how current is equal through all components in a series RC or RL circuit.

   H. Show how voltage is equal in each branch of a parallel RC or RL circuit.

   I. Explain the correct procedure for reading a trigonometric function table.

   J. Give test.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheets

   D. Transparency masters

      1. TM #1--Square, Square Root Table

      2. TM #2--Trigonometric Functions Table

   E. Assignment sheets

      1. Assignment Sheet #1--Calculate Parameters and Draw Vectors of a Series RC Circuit

      2. Assignment Sheet #2--Calculate Parameters and Draw Vectors of a Series RL Circuit

SUGGESTED ACTIVITIES

3. Assignment Sheet #3--Calculate Parameters and Draw Vectors of a Parallel RC Circuit

4. Assignment Sheet #4--Calculate Parameters and Draw Vectors of a Parallel RL Circuit

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1--Determine the Phase Difference in a Series RC Circuit

2. Job Sheet #2--Determine the Phase Difference in a Series RL Circuit

H. Test

I. Answers to test

III. Unit references:

A. Grob, Bernard. *Basic Electronics*. 4th ed. New York: McGraw-Hill Book Company, 1977.

B. Seippel, Robert G. *Alternating Current Circuit Analysis*. Chicago: American Technical Society, 1975.

RC AND RL CIRCUITS
UNIT VIII

INFORMATION SHEET

I. Terms and definitions

   A. Impedance--Total opposition to current flow in an AC circuit

      (NOTE: Impedance is measured in ohms.)

   B. Vector--Line used to represent magnitude and direction

   C. Pythagorean Theorem--In a right triangle, the square of the hypotenuse equals the sum of the squares of the other two sides

   D. Hypotenuse--Longest side of a right triangle; side opposite the right angle

   E. Phase angle--Angle of a right triangle which is adjacent to the hypotenuse; the angle on the X-axis which is not the right angle

   F. Power--Rate at which work is done; in electricity, it is the total voltage times the total current

   G. True power--Actual amount of power dissipated in a circuit

   H. Apparent power--Amount of power that seems to be dissipated in a circuit

   I. Power factor--Ratio between the true power and the apparent power of a circuit

      (NOTE: Power factor is always 1 or less.)

   J. Reactance--Opposition to the flow of current of capacitors and inductors

   K. Volt-ampere--Unit of measurement of apparent power

   L. Watt--Unit of measurement of true power

II. Abbreviations associated with RC and RL circuits

   A. X_C--Capacitive reactance

   B. X_L--Inductive reactance

   C. X--Reactance

   D. Z--Impedance

   E. P_f--Power factor

   F. RC--Resistive capacitive

INFORMATION SHEET

G. **RL**--Resistive inductive

H. **RCL**--Resistive capacitive inductive

I. **VA**--Volt-ampere

J. **W**--Watt

K. P_a--Apparent power

L. P_t--True power

III. Symbols associated with RC and RL circuits

A. $\sqrt{}$--Square root

B. π--Greek letter *pi* representing 3.14

C. $<\phi$--Phase angle

IV. Pythagorean Theorem as it applies to vectors--In a right triangle, the square of the hypotenuse equals the sum of the squares of the other two sides

V. Relationship of parts of right triangles to electronic vectors (Figure 1)

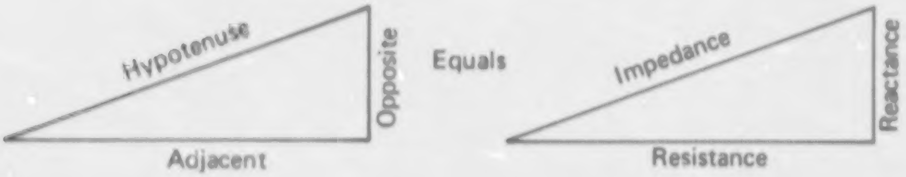
A. Hypotenuse equals impedance

B. Adjacent equals resistance

C. Opposite equals reactance

EXAMPLE:

FIGURE 1


Hypotenuse
Opposite
Adjacent
Equals
Impedance
Reactance
Resistance

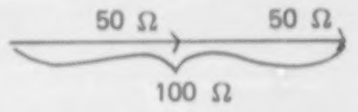
INFORMATION SHEET

VI. Vector diagram of the phase relationship between resistance, capacitance, and inductance (Figures 2-4)

A. Resistance is drawn on the horizontal axis

EXAMPLE: Two 50-ohm resistors

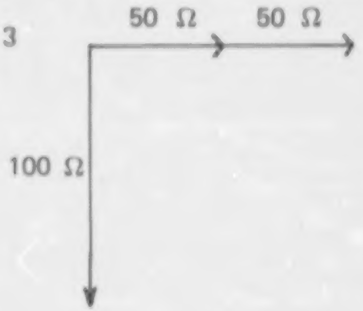
FIGURE 2



B. Capacitance is drawn downward from the horizontal axis

EXAMPLE: Two 50-ohm resistors and one 100-ohm capacitor

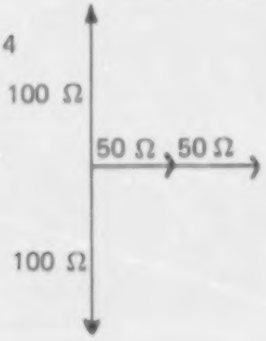
FIGURE 3



C. Inductance is drawn upward from the horizontal axis

EXAMPLE: Two 50-ohm resistors, one 100-ohm capacitor, and one 100-ohm inductor

FIGURE 4



INFORMATION SHEET

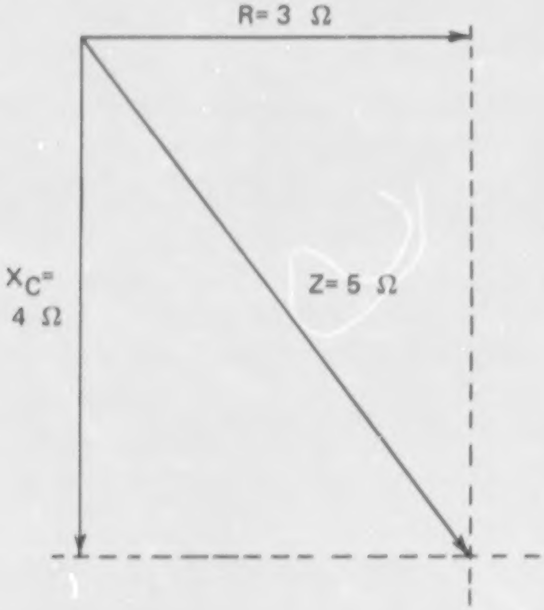
VII. Mathematical formula for calculating impedance of a series RC circuit--Use the formula $Z = \sqrt{R^2 + X_C^2}$

EXAMPLE: A series RC circuit has a resistance of 3 ohms and a capacitive reactance of 4 ohms

$$Z = \sqrt{R^2 + X_C^2}$$
$$= \sqrt{3^2 + 4^2}$$
$$= \sqrt{9 + 16}$$
$$= \sqrt{25}$$
$$= 5\ \Omega$$

(NOTE: Use Square, Square Root Table [Transparency #1], if needed. The vector diagram for the above circuit would be drawn by first drawing the resistance and capacitive reactance vectors. Next, lines would be drawn parallel to the resistance and capacitive reactance vectors. Finally a line would be drawn from the initial intersecting point of the resistance and capacitive reactance vectors to the intersecting point of the parallel lines. This would then be the impedance vector. See Figure 5.)

FIGURE 5



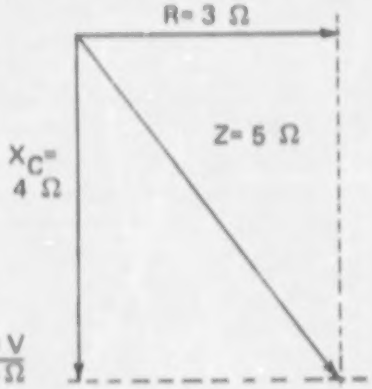
INFORMATION SHEET

VIII. Calculating current of a series RC or RL circuit--Use Ohm's Law, substituting impedance for resistance; use the formulas

$I = \frac{E}{R}$ or $I = \frac{E}{Z}$

EXAMPLE: Impedance in the vector shown in Figure 6 is 5 ohms. Using an applied voltage of 50 volts, find the current.

FIGURE 6



Solution: $I = \frac{E}{Z}$

$= \frac{50\text{ V}}{5\,\Omega}$

$= 10\text{ A}$

IX. Trigonometric functions that can be used to find the phase angle of a series RC or RL circuit

A. Tan $<\phi$

1. $\text{Tan} <\phi = \frac{\text{Opp}}{\text{Adj}}$
2. $\text{Tan} <\phi = \frac{X_C}{R}$

B. Sin ϕ

1. $\text{Sin} <\phi = \frac{\text{Opp}}{\text{Hyp}}$
2. $\text{Sin} <\phi = \frac{X_C}{Z}$

C. Cos ϕ

1. $\text{Cos} <\phi = \frac{\text{Adj}}{\text{Hyp}}$
2. $\text{Cos} <\phi = \frac{R}{Z}$

INFORMATION SHEET

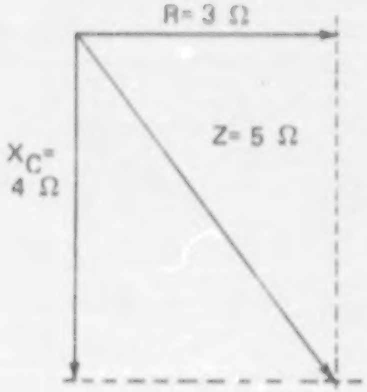
EXAMPLE: In the vector diagram in Figure 7, impedance equals 5 ohms and resistance equals 3 ohms. Using a Cos $<\phi$ formula, the phase angle would be found as follows

$$\text{Cos} <\phi = \frac{R}{Z}$$

$$= \frac{3\ \Omega}{5\ \Omega}$$

$$= 0.6$$

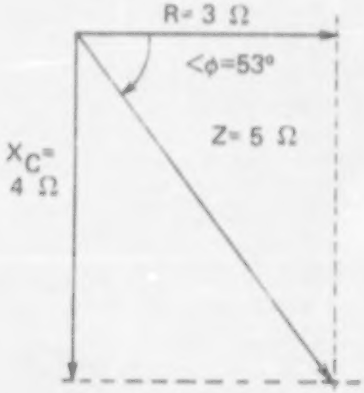
FIGURE 7



(NOTE: Now, find the angle of 0.6 in the Trigonometric Functions Table in Transparency #2. The Cos $<\phi$ should be 53° as shown in Figure 8.)

EXAMPLE:

FIGURE 8



(NOTE: To determine the phase angle of a series RL circuit, substitute X_L for X_C in the phase angle formulas.)

INFORMATION SHEET

X. Calculating voltage in a series RC circuit--Current is equal through each component, and the sum of the voltage drops does not equal the voltage applied

EXAMPLE: In the example circuit, resistance equals 3 ohms, capacitive reactance equals 4 ohms, impedance equals 5 ohms, and total current equals 10 amps; therefore,

$$E_R = I_R \times R$$

$$= 10\text{ A} \times 3\ \Omega$$

$$= 30\text{ V}$$

$$E_C = I_C \times X_C$$

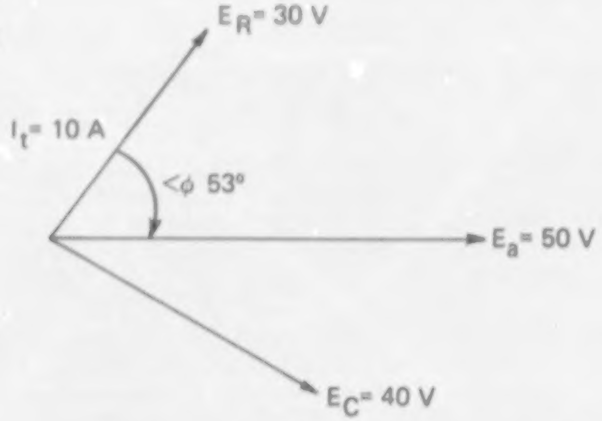
$$= 10\text{ A} \times 4\ \Omega$$

$$= 40\text{ V}$$

(NOTE: The sum of the voltage drops equals 70 volts, which is more than the 50 volts applied. This is due to the difference in times of the voltage drops. To draw a voltage vector, the voltage applied is on the horizontal reference line. Then use the phase angle found in the resistance vector (53°). Because current leads voltage by 90° in a capacitor, the current must be plotted above the voltage applied, and the capacitor voltage is plotted below. Because current and voltage are in phase in a resistor, E_R will be plotted on the same vector as I_t.)

EXAMPLE:

FIGURE 9



INFORMATION SHEET

XI. Calculate the applied voltage of a series RC or RL circuit--Use the Pythagorean Theorem

$$E_a = \sqrt{E_R^2 + E_C^2}$$

EXAMPLE: $E_a = \sqrt{E_R^2 + E_C^2}$

$= \sqrt{30^2 + 40^2}$

$= \sqrt{900 + 1,600}$

$= \sqrt{2,500}$

$= 50\ V$

(NOTE: In order to determine applied voltage of a series RL circuit replace E_C^2 with E_L^2 in the formula.)

XII. Mathematical formula for calculating impedance of a series RL circuit (Transparency #1)--$Z = \sqrt{R^2 + X_L^2}$

EXAMPLE: $Z = \sqrt{R^2 + X_L^2}$

$= \sqrt{6^2 + 8^2}$

$= \sqrt{36 + 64}$

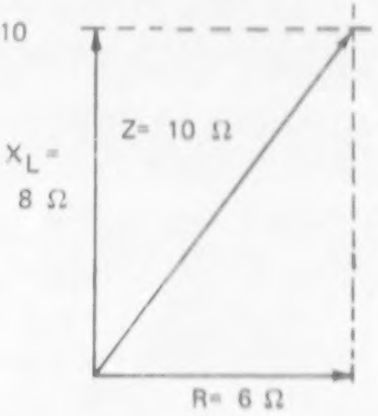
$= \sqrt{100}$

$= 10\ \Omega$

(NOTE: The impedance vector for the above circuit would look like the following example in Figure 10.)

EXAMPLE:

FIGURE 10



INFORMATION SHEET

XIII. Calculating voltage in a series RL circuit--Current is equal through each component, and the sum of the voltage drops does not equal the voltage applied

EXAMPLE: In the example circuit, resistance equals 6 ohms, inductive reactance equals 8 ohms, impedance equals 10 ohms, and total current equals 10 amps; therefore

$$E_R = I_R \times R$$

$$= 10\text{ A} \times 6\ \Omega$$

$$= 60\text{ V}$$

$$E_L = I_L \times X_L$$

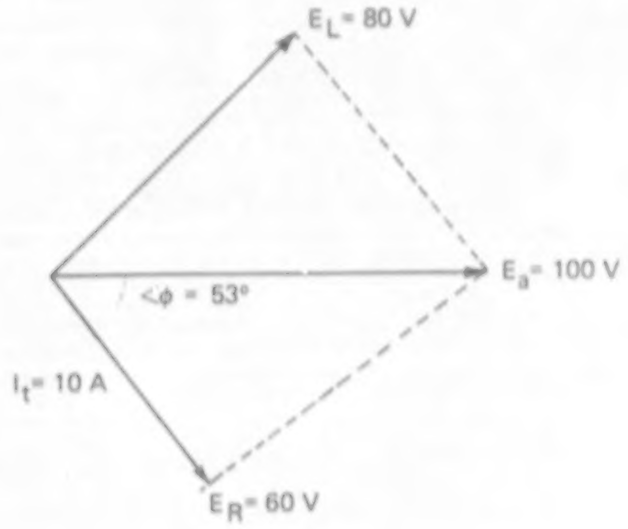
$$= 10\text{ A} \times 8\ \Omega$$

$$= 80\text{ V}$$

(NOTE: The sum of the voltage drops equals 140 volts, which is more than 100 volts applied. This also is due to the difference in times of the voltage drops. To draw a voltage vector, the voltage applied is again plotted on the horizontal reference line. Then the phase angle [53°] found in the resistance vector is used. Because voltage leads current by 90° in an inductive circuit, the current must be plotted below the voltage applied, and the inductor voltage is plotted above. Because current and voltage are in phase in a resistor, E_R will be plotted on the same vector as I_t. See Figure 11.)

EXAMP .

FIGURE 11



INFORMATION SHEET

XIV. Calculating power of a series RC or RL circuit

A. True power is the actual power dissipated by the resistance of the circuit; use the following formulas

$P_t = E_R \times I_R$ or $P_t = I_R^2 \times R$ or $P_t = \frac{E_R^2}{R}$

EXAMPLE: $P_t = E_R \times I_R$

$= 30\text{ V} \times 10\text{ A}$

$= 300\text{ W}$

(NOTE: True power is measured in watts just as in a purely resistive circuit.)

B. Apparent power is the power that seems to be dissipated but is not; use the following formulas

$P_a = E_a \times I_t$ or $P_a = \frac{E_a^2}{Z}$ or $P_a = I_t^2 \times Z$

EXAMPLE: $P_a = E_a \times I_t$

$= 50\text{ V} \times 10\text{ A}$

$= 500\text{ VA}$

(NOTE: Apparent power is measured in volt-amperes.)

C. Power factor is the ratio between true power and apparent power, usually expressed as a decimal of never more than 1; use the following formulas

$P_f = \frac{P_t}{P_a}$ or $P_f = \frac{E_R}{E_a}$ or $P_f = \frac{R}{Z}$ or $P_f = \text{Cos} \angle \phi$

EXAMPLE: $P_f = \frac{P_t}{P_a}$

$= \frac{300\text{ W}}{500\text{ VA}}$

$= .6$

INFORMATION SHEET

XV. Calculating current of a parallel RC circuit--Use the Pythagorean Theorem

(NOTE: The Pythagorean Theorem is used because voltage is equal in each branch of parallel RC circuits. The Pythagorean Theorem cannot be used for impedance because total resistance-reactance is less than the smallest branch.)

EXAMPLE: A parallel RC circuit has an applied voltage of 60 volts, a resistance of 3 ohms, and a capacitive reactance of 4 ohms

$$I_R = \frac{E_R}{R}$$

$$= \frac{60\ V}{3\ \Omega}$$

$$= 20\ A$$

and

$$I_C = \frac{E_C}{X_C}$$

$$= \frac{60\ V}{4\ \Omega}$$

$$= 15\ A$$

(NOTE: Once the individual currents have been calculated, the Pythagorean Theorem can be applied [Transparency #1].)

EXAMPLE: $I_t = \sqrt{I_R^2 + I_C^2}$

$$= \sqrt{20^2 + 15^2}$$

$$= \sqrt{400 + 225}$$

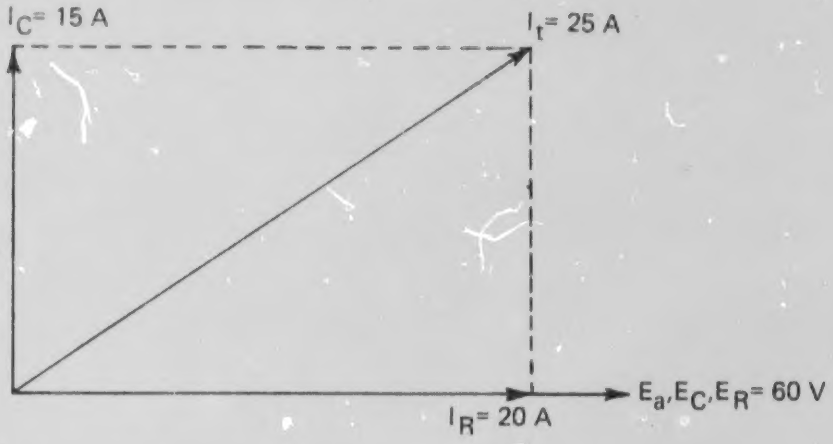
$$= \sqrt{625}$$

$$= 25\ A$$

(NOTE: All voltages in a parallel circuit are in phase and are drawn on the horizontal vector along with the resistor current. As shown in the following vector diagram [Figure 12], current through the capacitor is 90° ahead of voltage.)

INFORMATION SHEET

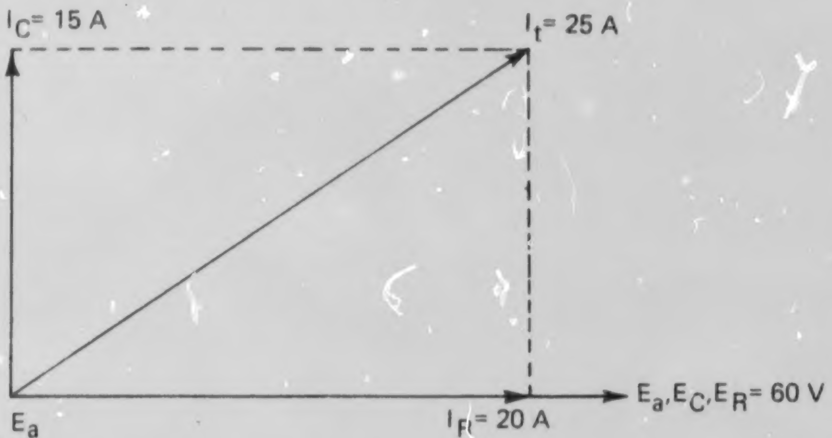
FIGURE 12


I_C = 15 A
I_t = 25 A
E_a, E_C, E_R = 60 V
I_R = 20 A

XVI. Calculating impedance of a parallel RC circuit--Use Ohm's Law

EXAMPLE: The vector shown in Figure 13 has a voltage applied of 60 volts and a total current of 25 amps. What is the impedance?

FIGURE 13


I_C = 15 A
I_t = 25 A
E_a, E_C, E_R = 60 V
I_R = 20 A

Solution: $Z = \frac{E_a}{I_t}$

$= \frac{60\text{ V}}{25\text{ A}}$

$= 2.4\ \Omega$

(NOTE: Impedance of a parallel RC or RL circuit can be calculated by using an assumed voltage as long as the resistance and reactance are known.)

INFORMATION SHEET

XVII. Calculating the phase angle of a parallel RC circuit--Use the formulas

$\text{Cos} < \phi = \frac{\text{Adj}}{\text{Hyp}}$ or $\text{Cos} < \phi = \frac{I_R}{I_t}$

EXAMPLE: $\text{Cos} < \phi = \frac{I_R}{I_t}$

$= \frac{20\ \text{A}}{25\ \text{A}}$

$= .8$

(NOTE: Now, locate .8 in the Trigonometric Functions Table in Transparency #2. Cos .8 should be 30°.)

XVIII. Calculating power of a parallel RC or RL circuit

A. True power is the actual power dissipated by the resistance of the circuit; use the formulas

$P_t = I_R \times E_R$ or $P_t = I_R^2 \times R$ or $P_t = \frac{E_R^2}{R}$

(NOTE: True power is measured in watts just as in a purely resistive circuit.)

EXAMPLE: $P_t = I_R \times E_R$

$= 20\ \text{A} \times 60\ \text{V}$

$= 1200\ \text{W}$

B. Apparent power is the power that seems to be dissipated but is not; use the formulas

$P_a = I_t \times E_a$ or $P_a = I_t^2 \times Z$ or $P_a = \frac{E_a^2}{Z}$

(NOTE: Apparent power is measured in volt-amperes or VA.)

EXAMPLE: $P_a = I_t \times E_a$

$= 25\ \text{A} \times 60\ \text{V}$

$= 1500\ \text{VA}$

INFORMATION SHEET

C. Power factor is the ratio between true power and apparent power, usually expressed as a decimal of never more than 1; use the formulas

$P_f = \frac{P_t}{P_a}$ or $P_f = \frac{I_R}{I_t}$ or $P_f = \frac{Z}{R}$ or $P_f = \text{Cos} \angle \phi$

EXAMPLE: $P_f = \frac{P_t}{P_a}$

$= \frac{1200 \text{ W}}{1500 \text{ VA}}$

$= .8$

XIX. Calculating current of a parallel RL circuit--Process is identical to calculating parallel RC circuits, except for phase relationship

EXAMPLE: A parallel RL circuit has an applied voltage of 40 volts, a resistance of 10 ohms, and an inductive reactance of 8 ohms

$I_R = \frac{E_R}{R}$

$= \frac{40 \text{ V}}{10\ \Omega}$

$= 4 \text{ A}$

$I_L = \frac{E_L}{X_L}$

$= \frac{40 \text{ V}}{8\ \Omega}$

$= 5 \text{ A}$

(NOTE: Once the individual currents have been calculated, the Pythagorean Theorem can be used to calculate total current.)

EXAMPLE: $I_t = \sqrt{I_R{}^2 + I_L{}^2}$

$= \sqrt{4^2 + 5^2}$

$= \sqrt{16 + 25}$

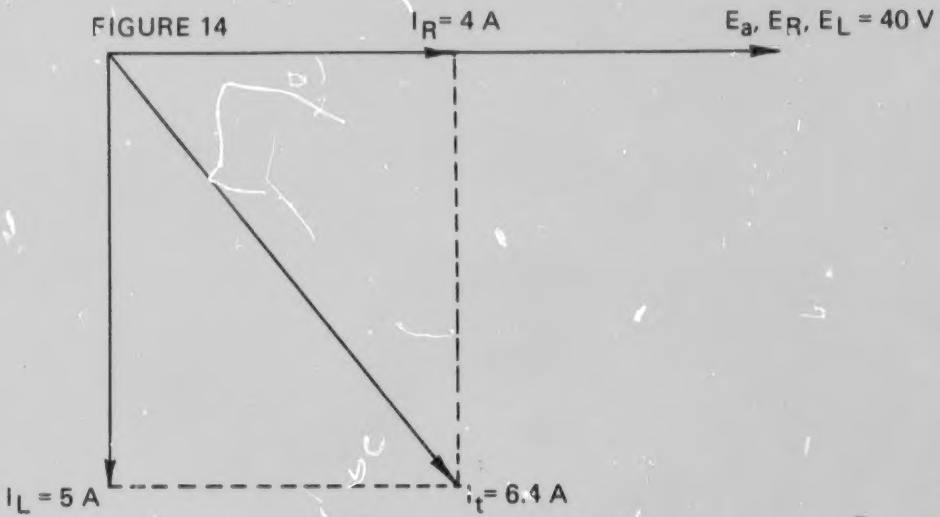
$= \sqrt{41}$

$= 6.4 \text{ A}$

(NOTE: A vector diagram for this problem would look like the following example in Figure 14.)

INFORMATION SHEET

FIGURE 14



XX. Calculating impedance of a parallel RL circuit--Use the formula $Z = \frac{E_a}{I_t}$

(NOTE: Impedance must be calculated using ohms.)

EXAMPLE: If a parallel circuit has an applied voltage of 40 volts and a total current of 6.4 amps, what is the impedance?

Solution: $Z = \frac{E_a}{I_t}$

$= \frac{40\text{ V}}{6.4\text{ A}}$

$= 6.25\ \Omega$

XXI. Calculating the phase angle of a parallel RL circuit--Use the formulas

$\text{Cos} < \phi = \frac{\text{Adj}}{\text{Hyp}}$ or $\text{Cos} < \phi = \frac{I_R}{I_t}$

EXAMPLE: $\text{Cos} < \phi = \frac{I_R}{I_t}$

$= \frac{4\text{ A}}{6.4\text{ A}}$

$= 0.625$

(NOTE: Now find the angle of 0.625 in the Trigonometric Functions Table in Transparency #2. The Cos <ϕ should be 51°.)

Square, Square Root Table

No.	Square	Sq. Root	Reciprocal	No.	Square	Sq. Root	Reciprocal
1	1	1.00000	1.0000000	51	2,601	7.14143	0.0196078
2	4	1.41421	0.5000000	52	2,704	7.21110	0.0192308
3	9	1.73205	0.3333333	53	2,809	7.28011	0.0188679
4	16	2.00000	0.2500000	54	2,916	7.34847	0.0185185
5	25	2.23607	0.2000000	55	3,025	7.41620	0.0181818
6	36	2.44949	0.1666667	56	3,136	7.48331	0.0178571
7	49	2.64575	0.1428571	57	3,249	7.54983	0.0175439
8	64	2.82843	0.1250000	58	3,364	7.61577	0.0172414
9	81	3.00000	0.1111111	59	3,481	7.68115	0.0169492
10	100	3.16228	0.1000000	60	3,600	7.74597	0.0166667
11	121	3.31662	0.0909091	61	3,721	7.81025	0.0163934
12	144	3.46410	0.0833333	62	3,844	7.87401	0.0161290
13	169	3.60555	0.0769231	63	3,969	7.93725	0.0158730
14	196	3.74166	0.0714286	64	4,096	8.00000	0.0156250
15	225	3.87298	0.0666667	65	4,225	8.06226	0.0153846
16	256	4.00000	0.0625000	66	4,356	8.12404	0.0151515
17	289	4.12311	0.0588235	67	4,489	8.18535	0.0149254
18	324	4.24264	0.0555556	68	4,624	8.24621	0.0147059
19	361	4.35890	0.0526316	69	4,761	8.30662	0.0144928
20	400	4.47214	0.0500000	70	4,900	8.36660	0.0142857
21	441	4.58258	0.0476190	71	5,041	8.42615	0.0140845
22	484	4.69042	0.0454545	72	5,184	8.48528	0.0138889
23	529	4.79583	0.0434783	73	5,329	8.54400	0.0136986
24	576	4.89898	0.0416667	74	5,476	8.60233	0.0135135
25	625	5.00000	0.0400000	75	5,625	8.66025	0.0133333
26	676	5.09902	0.0384615	76	5,776	8.71780	0.0131579
27	729	5.19615	0.0370370	77	5,929	8.77496	0.0129870
28	784	5.29150	0.0357143	78	6,084	8.83176	0.0128205
29	841	5.38516	0.0344828	79	6,241	8.88819	0.0126582
30	900	5.47723	0.0333333	80	6,400	8.94427	0.0125000
31	961	5.56776	0.0322581	81	6,561	9.00000	0.0123457
32	1,024	5.65685	0.0312500	82	6,724	9.05539	0.0121951
33	1,089	5.74456	0.0303030	83	6,889	9.11043	0.0120482
34	1,156	5.83095	0.0294118	84	7,056	9.16515	0.0119048
35	1,225	5.91608	0.0285714	85	7,225	9.21954	0.0117647
36	1,296	6.00000	0.0277778	86	7,396	9.27362	0.0116279
37	1,369	6.08276	0.0270270	87	7,569	9.32738	0.0114943
38	1,444	6.16441	0.0263158	88	7,744	9.38083	0.0113636
39	1,521	6.24500	0.0256410	89	7,921	9.43398	0.0112360
40	1,600	6.32456	0.0250000	90	8,100	9.48683	0.0111111
41	1,681	6.40312	0.0243902	91	8,281	9.53939	0.0109890
42	1,764	6.48074	0.0238095	92	8,464	9.59166	0.0108696
43	1,849	6.55744	0.0232558	93	8,649	9.64365	0.0107527
44	1,936	6.63325	0.0227273	94	8,836	9.69536	0.0106383
45	2,025	6.70820	0.0222222	95	9,025	9.74679	0.0105263
46	2,116	6.78233	0.0217391	96	9,216	9.79796	0.0104167
47	2,209	6.85565	0.0212766	97	9,409	9.84886	0.0103093
48	2,304	6.92820	0.0208333	98	9,604	9.89949	0.0102041
49	2,401	7.00000	0.0204082	99	9,801	9.94987	0.0101010
50	2,500	7.07107	0.0200000	100	10,000	10.00000	0.0100000

Trigonometric Functions Table

ANGLE	SIN	COS	TAN	ANGLE	SIN	COS	TAN
0°	0.0000	1.0000	0.0000	45°	0.7071	0.7071	1.0000
1	.0175	.9998	.0175	46	.7193	.6947	1.0355
2	.0349	.9994	.0349	47	.7314	.6820	1.0724
3	.0523	.9986	.0524	48	.7431	.6691	1.1106
4	.0698	.9976	.0699	49	.7547	.6561	1.1504
5	.0872	.9962	.0875	50	.7660	.6428	1.1918
6	.1045	.9945	.1051	51	.7771	.6293	1.2349
7	.1219	.9925	.1228	52	.7880	.6157	1.2799
8	.1392	.9903	.1405	53	.7986	.6018	1.3270
9	.1564	.9877	.1548	54	.8090	.5878	1.3764
10	.1736	.9848	.1763	55	.8192	.5736	1.4281
11	.1908	.9816	.1944	56	.8290	.5592	1.4826
12	.2079	.9781	.2126	57	.8387	.5446	1.5399
13	.2250	.9744	.2309	58	.8480	.5299	1.6003
14	.2419	.9703	.2493	59	.8572	.5150	1.6643
15	.2588	.9659	.2679	60	.8660	.5000	1.7321
16	.2756	.9613	.2867	61	.8746	.4848	1.8040
17	.2924	.9563	.3057	62	.8829	.4695	1.8807
18	.3090	.9511	.3249	63	.8910	.4540	1.9626
19	.3256	.9455	.3443	64	.8988	.4384	2.0503
20	.3420	.9397	.3640	65	.9063	.4226	2.1445
21	.3584	.9336	.3839	66	.9135	.4067	2.2460
22	.3746	.9272	.4040	67	.9205	.3907	2.3559
23	.3907	.9205	.4245	68	.9272	.3746	2.4751
24	.4067	.9135	.4452	69	.9336	.3584	2.6051
25	.4226	.9063	.4663	70	.9397	.3420	2.7475
26	.4384	.8988	.4877	71	.9455	.3256	2.9042
27	.4540	.8911	.5095	72	.9511	.3090	3.0777
28	.4695	.8829	.5317	73	.9563	.2924	3.2709
29	.4848	.8746	.5543	74	.9613	.2756	3.4874
30	.5000	.8660	.5774	75	.9659	.2588	3.7321
31	.5150	.8572	.6009	76	.9703	.2419	4.0108
32	.5299	.8480	.6249	77	.9744	.2250	4.3315
33	.5446	.8387	.6494	78	.9781	.2079	4.7046
34	.5592	.8290	.6745	79	.9816	.1908	5.1446
35	.5736	.8192	.7002	80	.9848	.1736	5.6713
36	.5878	.8090	.7265	81	.9877	.1564	6.3138
37	.6018	.7986	.7536	82	.9903	.1392	7.1154
38	.6157	.7880	.7813	83	.9925	.1219	8.1443
39	.6293	.7771	.8098	84	.9945	.1045	9.5144
40	.6428	.7660	.8391	85	.9962	.0872	11.43
41	.6561	.7547	.8693	86	.9976	.0698	14.30
42	.6691	.7431	.9004	87	.9986	.0523	19.08
43	.6820	.7314	.9325	88	.9994	.0349	28.64
44	.6947	.7193	.9657	89	.9998	.0175	57.29
				90	1.0000	.0000	---------

RC AND RL CIRCUITS
UNIT VIII

ASSIGNMENT SHEET #1--CALCULATE PARAMETERS AND DRAW VECTORS OF A SERIES RC CIRCUIT

NAME ______________________________ SCORE ______________

Industries use a variety of circuit configurations in order to create different reactions in electronic equipment. One of these configurations is a series RC circuit. This particular circuit has an input voltage of 40 volts, a resistance of 12 ohms, and a capacitive reactance of 16 ohms.

Using the Pythagorean Theorem and Ohm's Law, calculate impedance, current, phase angle, voltage, and power of the circuit described above; then plot impedance and voltage vectors.

A. Z = ______________________________

B. $<\phi$ = ______________________________

C. I_t = ______________________________

D. E_C = ______________________________

E. E_R = ______________________________

F. P_t = ______________________________

G. P_a = ______________________________

H. P_f = ______________________________

I. Impedance vector

J. Voltage vector

RC AND RL CIRCUITS
UNIT VIII

ASSIGNMENT SHEET #2--CALCULATE PARAMETERS AND DRAW VECTORS OF A SERIES RL CIRCUIT

NAME ______________________ SCORE ____________

Another circuit configuration used by industries is the series RL circuit, which gives a different phase relationship between current and voltage. This circuit has an applied voltage of 100 volts, a resistance of 14 ohms, and an inductive reactance of 48 ohms.

Using the Pythagorean Theorem and Ohm's Law, calculate impedance, current, phase angle, voltage, and power of the circuit described above; then plot impedance and voltage vectors.

A. Z = ______________________

B. $<\phi$ = ______________________

C. I_t = ______________________

D. E_C = ______________________

E. E_R = ______________________

F. P_t = ______________________

G. P_a = ______________________

H. F_f = ______________________

I. Impedance vector

J. Voltage vector

RC AND RL CIRCUITS
UNIT VIII

ASSIGNMENT SHEET #3--CALCULATE PARAMETERS AND DRAW VECTORS OF A PARALLEL RC CIRCUIT

NAME ______________________________ SCORE ______________

By changing the configuration of a circuit from a series circuit to a parallel circuit, a difference of current rather than voltage will be seen. This circuit has an input voltage of 240 volts, a resistance of 8 ohms, and a capacitive reactance of 6 ohms.

Using the Pythagorean Theorem and Ohm's Law, calculate impedance, current, phase angle, voltage, and power of the circuit described above; then plot current vectors.

A. $Z =$ ______________________________

B. $<\phi =$ ______________________________

C. $I_t =$ ______________________________

D. $I_R =$ ______________________________

E. $I_C =$ ______________________________

F. $P_t =$ ______________________________

G. $P_a =$ ______________________________

H. $P_f =$ ______________________________

I. Current vector

RC AND RL CIRCUITS
UNIT VIII

ASSIGNMENT SHEET #4--CALCULATE PARAMETERS AND DRAW VECTORS OF A PARALLEL RL CIRCUIT

NAME ________________________________ SCORE ______________

By again changing the circuit configuration from an RC circuit to an RL circuit there will be a change in the phase relationship available to industry for circuit configuration capability. This parallel RL circuit has an input voltage of 120 volts, a resistance of 24 ohms, and an inductive reactance of 10 ohms.

Using the Pythagorean Theorem and Ohm's Law, calculate impedance, current, phase angle, voltage, and power of the circuit described above; then plot current vectors.

A. $Z =$ ________________________________

B. $<\phi =$ ________________________________

C. $I_t =$ ________________________________

D. $I_R =$ ________________________________

E. $I_L =$ ________________________________

F. $P_t =$ ________________________________

G. $P_a =$ ________________________________

H. $P_f =$ ________________________________

I. Current vector

RC AND RL CIRCUITS
UNIT VIII

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 20 Ω

B. 53°

C. 2 A

D. 32 V

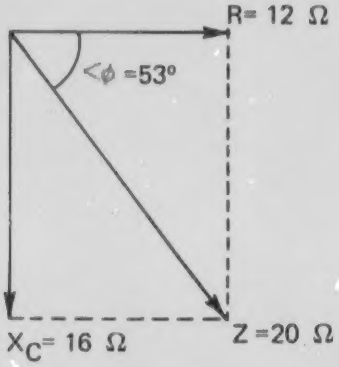
E. 24 V

F. 48 W

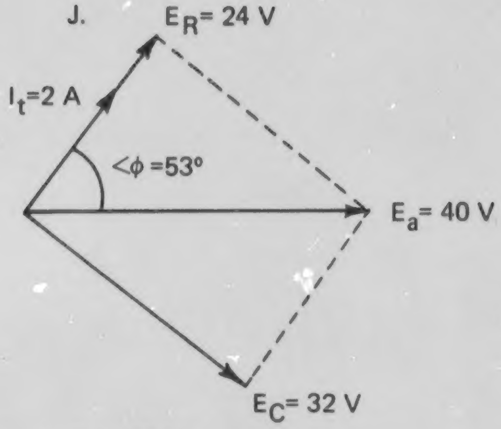
G. 80 VA

H. .6

I.


R= 12 Ω
<ϕ =53°
X_C= 16 Ω
Z =20 Ω

J.


E_R= 24 V
I_t=2 A
<ϕ =53°
E_a= 40 V
E_C= 32 V

Assignment Sheet #2

A. 50 Ω

B. 73°

C. 2 A

D. 96 V

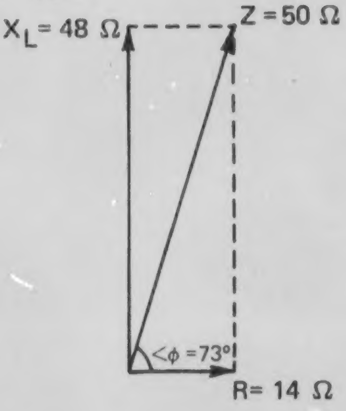
E. 28 V

F. 56 W

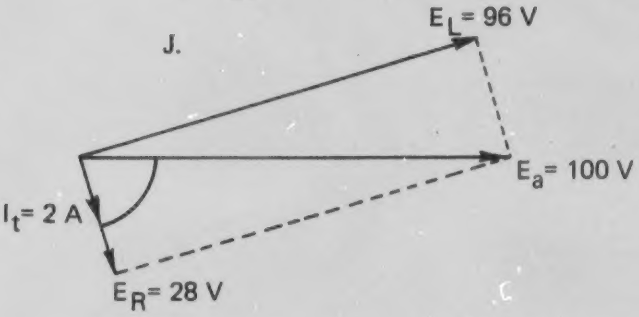
G. 200 VA

H. .28

I.


X_L= 48 Ω
Z =50 Ω
<ϕ =73°
R= 14 Ω

J.


E_L= 96 V
E_a= 100 V
I_t= 2 A
E_R= 28 V

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #3

A. 4.8 Ω

B. 53°

C. 50 A

D. 30 A

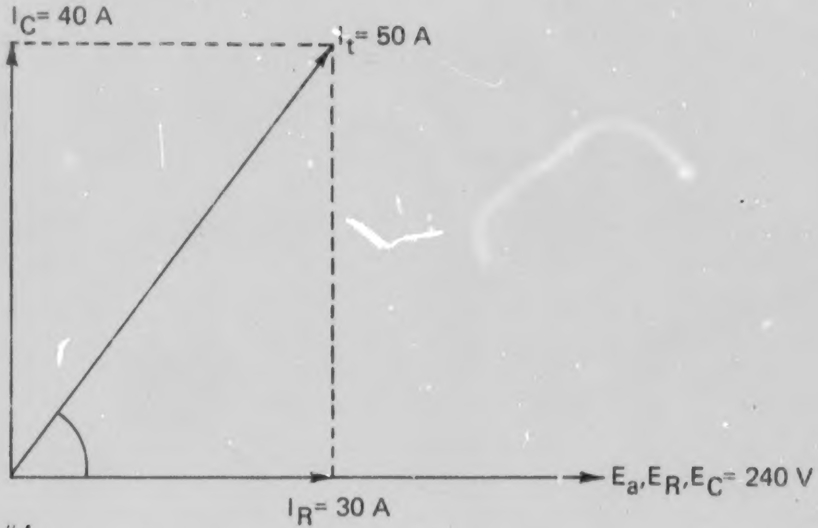
E. 40 A

F. 7,200 W

G. 12,000 VA

H. .6

I.


I_C= 40 A
I_t= 50 A
E_a,E_R,E_C= 240 V
I_R= 30 A

Assignment Sheet #4

A. 9.2 Ω

B. 67°

C. 13 A

D. 5 A

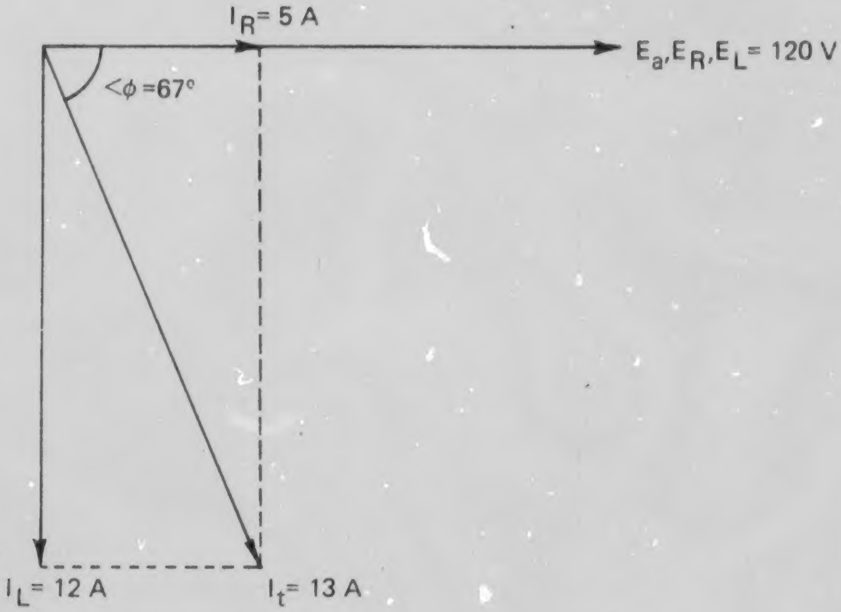
E. 12 A

F. 600 W

G. 1,560 VA

H. .3846

I.


I_R= 5 A
E_a,E_R,E_L= 120 V
<ϕ =67°
I_L= 12 A
I_t= 13 A

RC AND RL CIRCUITS
UNIT VIII

JOB SHEET #1--DETERMINE THE PHASE DIFFERENCE IN A SERIES RC CIRCUIT

I. Equipment and materials

- A. Dual-trace oscilloscope
- B. Function generator
- C. Frequency counter
- D. Oscilloscope probes
- E. Resistor--6.8 Kohms
- F. Capacitor--220 pF
- G. Test leads

II. Procedure

A. Connect function generator, resistor, and capacitor in series

B. Adjust output of function generator to 106 kHz

(NOTE: Frequency can be measured by using the oscilloscope or the frequency counter.)

C. Connect Channel A of the oscilloscope to the generator output

D. Connect Channel B of the oscilloscope to the connection between the capacitor and resistor

E. Measure the phase difference shown on the oscilloscope

F. Record your answer

Phase difference = ______________________________

G. Calculate the phase difference

H. Record your answer

Calculated phase difference = ______________________________

I. Are the answers in F and H above the same? ____________________

(NOTE: Discuss your answers with your instructor.)

J. Turn off test equipment

K. Put equipment and materials away

(NOTE: Other combinations of resistors, capacitors, and frequencies can be used with the approval of your instructor.)

RC AND RL CIRCUITS
UNIT VIII

JOB SHEET #2--DETERMINE THE PHASE DIFFERENCE IN A SERIES RL CIRCUIT

I. Equipment and materials

- A. Dual-trace oscilloscope
- B. Function generator
- C. Frequency counter
- D. Oscilloscope probes
- E. Resistor--6.8 Kohms
- F. Inductor--10 mH
- G. Test leads

II. Procedure

- A. Connect function generator, resistor, and inductor in series
- B. Adjust output of function generator to 106 kHz

  (NOTE: Frequency can be measured by using the oscilloscope or the frequency counter.)
- C. Connect Channel A of the oscilloscope to the generator output
- D. Connect Channel B of the oscilloscope to the connection between the capacitor and resistor
- E. Measure the phase difference shown on the oscilloscope
- F. Record your answer

  Phase difference = ____________________
- G. Calculate the phase difference
- H. Record your answer

  Calculated phase difference = ____________________
- I. Are the answers in F and H above the same? ____________

  (NOTE: Discuss your answers with your instructor.)
- J. Turn off test equipment
- K. Put equipment and materials away

  (NOTE: Other combinations of resistors, capacitors, and frequencies can be used with the approval of your instructor.)

RC AND RL CIRCUITS
UNIT VIII

TEST

NAME ____ SCORE__________________

1. Match terms associated with RC and RL circuits to their correct definitions. Write the correct numbers in the blanks.

_____a. In a right triangle, the square of the hypotenuse equals the sum of the squares of the other two sides

_____b. Total opposition to current flow in an AC circuit

_____c. Longest side of a right triangle; side opposite the right angle

_____d. Line used to represent magnitude and direction

_____e. Rate at which work is done; in electricity, it is the total voltage times the total current

_____f. Angle of a right triangle which is adjacent to the hypotenuse; the angle on the X-axis which is not the right angle

_____g. Ratio between the true power and the apparent power of a circuit

_____h. Unit of measurement of true power

_____i. Amount of power that seems to be dissipated in a circuit

_____j. Opposition to the flow of current of capacitors and inductors

_____k. Actual amount of power dissipated in a circuit

_____l. Unit of measurement of apparent power

1. Hypotenuse
2. Watt
3. Pythagorean Theorem
4. Power
5. Power factor
6. Vector
7. Impedance
8. Volt-ampere
9. True power
10. Phase angle
11. Apparent power
12. Reactance

TEST

2. Match abbreviations associated with RC and RL circuits to their correct definitions. Write the correct numbers in the blanks.

_____ a. Reactance
_____ b. Capacitive reactance
_____ c. Volt-ampere
_____ d. Power factor
_____ e. Resistive capacitive
_____ f. Resistive inductive
_____ g. True power
_____ h. Inductive reactance
_____ i. Impedance
_____ j. Resistive capacitive inductive
_____ k. Watt
_____ l. Apparent power

1. Z
2. RC
3. X_C
4. RL
5. X_L
6. P_f
7. X
8. W
9. VA
10. P_t
11. P_a
12. RCL

3. Label symbols associated with RC and RL circuits.

a. π = ____

b. $\surd$ = ____

c. $<\phi$ = ____

4. State the Pythagorean Theorem as it applies to vectors.

____

____

____

5. Select from the following list correct statements about the relationship of parts of right triangles to electronic vectors. Write an "X" in the blanks before the correct answers.

_____ a. Adjacent equals impedance
_____ b. Hypotenuse equals impedance
_____ c. Opposite equals reactance
_____ d. Hypotenuse equals reactance

TEST

_____e. Opposite equals resistance

_____f. Adjacent equals resistance

6. Draw in the space below a vector diagram of the phase relationship between resistance, capacitance, and inductance.

7. Calculate impedance of a series RC circuit.

   Resistance is 12 ohms, and capacitive reactance is 16 ohms.

   Z = ____

8. Calculate current of a series RC circuit.

   Resistance is 12 ohms, impedance is 20 ohms, capacitive reactance is 16 ohms, and the applied voltage is 360 volts.

   I = ____

TEST

9. Calculate the phase angle of a series RC circuit.

(NOTE: Use the Trigonometric Functions Table at the end of the test.)

Resistance is 15 ohms, and capacitive reactance is 20 ohms.

$<\phi =$ ____________________________

10. Calculate voltages in a series RC circuit.

Resistance is 32 ohms, capacitive reactance is 60 ohms, impedance is 68 ohms, current is 4 amps, and voltage is 272 volts.

a. $E_R =$ ____________________________

b. $E_C =$ ____________________________

11. Calculate the applied voltage of a series RC circuit.

Resistance is 30 ohms, capacitive reactance is 40 ohms, total current is 6 amps, resistor voltage is 180 V, and capacitive voltage is 240 V.

$E_a =$ ____________________________

TEST

12. Calculate impedance of a series RL circuit.

Resistance is 24 Kohms and inductive reactance is 7 Kohms.

Z = ______________________________

13. Calculate voltages in a series RL circuit.

Applied voltage is 125 volts, resistance is 24 Kohms, impedance is 25 Kohms, inductive reactance is 7 Kohms, and total current is 5 mA.

a. E_L = ______________________________

b. E_R = ______________________________

14. Calculate power of a series RC or RL circuit.

Resistance is 10 ohms, capacitive reactance is 24 ohms, impedance is 26 ohms, and voltage is 260 volts.

a. P_t = ______________________________

b. P_a = ______________________________

c. P_f = ______________________________

TEST

15. Calculate current of a parallel RC circuit.

Resistance is 40 ohms, capacitive reactance is 30 ohms, and voltage is 360 volts.

a. I_R = ______________________

b. I_C = ______________________

c. I_t = ______________________

16. Calculate impedance of a parallel RC circuit.

Resistance is 100 ohms and capacitive reactance is 75 ohms.

Z = ______________________

17. Calculate the phase angle of a parallel RC circuit.

(NOTE: Use the Trigonometric Functions Table at the end of the test.)

Resistance is 30 ohms, and capacitive reactance is 40 ohms.

$<\phi$ = ____________ ________

TEST

18. Calculate power of a parallel RC or RL circuit.

Resistor current is 14 amps, capacitive current is 48 amps, and voltage is 120 volts.

a. P_t = ______________________________

b. P_a = ______________________________

c. P_f = ______________________________

19. Calculate current of a parallel RL circuit.

Resistance is 48 Kohms, inductive reactance is 14 Kohms, and voltage is 672 volts.

a. I_R = ______________________________

b. I_L = ______________________________

c. I_t = ______________________________

20. Calculate impedance of a parallel RL circuit.

Resistance is 75 ohms and an inductive reactance is 100 ohms.

Z = ____________________________________

TEST

21. Calculate the phase angle of a parallel RL circuit.

(NOTE: Use the Trigonometric Functions Table at the end of the test.)

Inductive reactance is 100 ohms, impedance is 60 ohms, and resistance is 75 ohms.

$<\phi =$ ______________________________

(NOTE: Test questions 22-26 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

22. Calculate parameters and draw vectors of a series RC circuit.

23. Calculate parameters and draw vectors of a series RL circuit.

24. Calculate parameters and draw vectors of a parallel RC circuit.

25. Calculate parameters and draw vectors of a parallel RL circuit.

26. Demonstrate the ability to

    a. Determine the phase difference in a series RC circuit.

    b. Determine the phase difference in a series RL circuit.

TEST

TRIGONOMETRIC FUNCTIONS TABLE

ANGLE	SIN	COS	TAN	ANGLE	SIN	COS	TAN
0°	0.0000	1.0000	0.0000	45°	0.7071	0.7071	1.0000
1	.0175	.9998	.0175	46	.7193	.6947	1.0355
2	.0349	.9994	.0349	47	.7314	.6820	1.0724
3	.0523	.9986	.0524	48	.7431	.6691	1.1106
4	.0698	.9976	.0699	49	.7547	.6561	1.1504
5	.0872	.9962	.0875	50	.7660	.6428	1.1918
6	.1045	.9945	.1051	51	.7771	.6293	1.2349
7	.1219	.9925	.1228	52	.7880	.6157	1.2799
8	.1392	.9903	.1405	53	.7986	.6018	1.3270
9	.1564	.9877	.1548	54	.8090	.5878	1.3764
10	.1736	.9848	.1763	55	.8192	.5736	1.4281
11	.1908	.9816	.1944	56	.8290	.5592	1.4826
12	.2079	.9781	.2126	57	.8387	.5446	1.5399
13	.2250	.9744	.2309	58	.8480	.5299	1.6003
14	.2419	.9703	.2493	59	.8572	.5150	1.6643
15	.2588	.9659	.2679	60	.8660	.5000	1.7321
16	.2756	.9613	.2867	61	.8746	.4848	1.8040
17	.2924	.9563	.3057	62	.8829	.4695	1.8807
18	.3090	.9511	.3249	63	.8910	.4540	1.9626
19	.3256	.9455	.3443	64	.8988	.4384	2.0503
20	.3420	.9397	.3640	65	.9063	.4226	2.1445
21	.3584	.9336	.3839	66	.9135	.4067	2.2460
22	.3746	.9272	.4040	67	.9205	.3907	2.3559
23	.3907	.9205	.4245	68	.9272	.3746	2.4751
24	.4067	.9135	.4452	69	.9336	.3584	2.6051
25	.4226	.9063	.4663	70	.9397	.3420	2.7475
26	.4384	.8988	.4877	71	.9455	.3256	2.9042
27	.4540	.8911	.5095	72	.9511	.3090	3.0777
28	.4695	.8829	.5317	73	.9563	.2924	3.2709
29	.4848	.8746	.5543	74	.9613	.2756	3.4874
30	.5000	.8660	.5774	75	.9659	.2588	3.7321
31	.5150	.8572	.6009	76	.9703	.2419	4.0108
32	.5299	.8480	.6249	77	.9744	.2250	4.3315
33	.5446	.8387	.6494	78	.9781	.2079	4.7046
34	.5592	.8290	.6745	79	.9816	.1908	5.1446
35	.5736	.8192	.7002	80	.9848	.1736	5.6713
36	.5878	.8090	.7265	81	.9877	.1564	6.3138
37	.6018	.7986	.7536	82	.9903	.1392	7.1154
38	.6157	.7880	.7813	83	.9925	.1219	8.1443
39	.6293	.7771	.8098	84	.9945	.1045	9.5144
40	.6428	.7660	.8391	85	.9962	.0872	11.43
41	.6561	.7547	.8693	86	.9976	.0698	14.30
42	.6691	.7431	.9004	87	.9986	.0523	19.08
43	.6820	.7314	.9325	88	.9994	.0349	28.64
44	.6947	.7193	.9657	89	.9998	.0175	57.29
				90	1.0000	.0000	....

RC AND RL CIRCUITS
UNIT VIII

ANSWERS TO TEST

1. a. 3
   b. 7
   c. 1
   d. 6
   e. 4
   f. 10
   g. 5
   h. 2
   i. 11
   j. 12
   k. 9
   l. 8

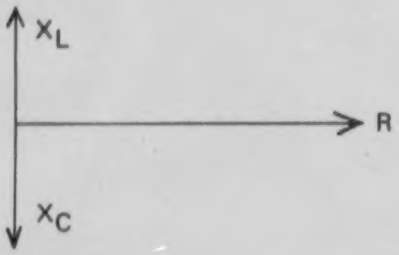
2. a. 7
   b. 3
   c. 9
   d. 6
   e. 2
   f. 4
   g. 10
   h. 5
   i. 1
   j. 12
   k. 8
   l. 11

3. a. Greek letter *pi* representing 3.14
   b. Square root
   c. Phase angle

4. In a right triangle, the square of the hypotenuse equals the sum of the squares of the other two sides

5. b, c, f

6.



ANSWERS TO TEST

7. 20 Ω
8. 18 A
9. 53°
10. a. 128 V
    b. 240 V
11. 300 V
12. 25 Kohms
13. a. 35 V
    b. 120 V

14. a. 1,000 W
    b. 2,600 VA
    c. .3846

15. a. 9 A
    b. 12 A
    c. 15 A
16. 60 Ω
17. 36.87°
18. a. 1,680 W
    b. 6,000 VA
    c. .28

19. a. 14 mA
    b. 48 mA
    c. 50 mA
20. 60 Ω
21. 36.87°

ANSWERS TO TEST

22. Evaluated to satisfaction of instructor
23. Evaluated to satisfaction of instructor
24. Evaluated to satisfaction of instructor
25. Evaluated to satisfaction of instructor
26. Performance skills evaluated to satisfaction of instructor

IMPEDANCE AND RESONANCE
UNIT IX

UNIT OBJECTIVE

After completing this unit, the student should be able to determine resonant frequency of an RCL circuit, and determine quality factor and bandwidth and bandpass of RCL circuits. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with impedance and resonance to their correct definitions.
2. Match symbols and abbreviations associated with impedance and resonance to their correct definitions.
3. Name the factors of impedance.
4. State phase relationships between voltage and current for each of the three factors of impedance.
5. Calculate impedance of a series RCL circuit.
6. Calculate phase angle of a series RCL circuit.
7. Calculate current and voltage of a series RCL circuit.
8. Calculate power of a series RCL circuit.
9. Calculate resonant frequency of a series or parallel RCL circuit.
10. Determine the quality factor of series and parallel RCL circuits.
11. Determine bandwidth and bandpass of a series or parallel RCL circuit.
12. Calculate current of a parallel RCL circuit.
13. Determine the phase angle of a parallel RCL circuit.
14. Determine impedance of a parallel RCL circuit.
15. Calculate power of a parallel RCL circuit.
16. Determine tank impedance and circuit impedance of a parallel RCL circuit.
17. Determine harmonic frequencies.

OBJECTIVE SHEET

18. Determine parameters of a series or parallel RCL circuit.

19. Calculate characteristics of a series RCL circuit.

20. Calculate characteristics of a parallel RCL circuit.

21. Determine characteristics of RCL circuits with varying parameters.

22. Demonstrate the ability to

    a. Determine resonant frequency of a series RCL circuit.

    b. Observe effects of series and parallel capacitors.

IMPEDANCE AND RESONANCE
UNIT IX

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Show how $X_L = 2\pi fL$ and $X_C = \frac{1}{2\pi fC}$ can be used to develop $F_r = \frac{1}{2\pi\sqrt{LC}}$ when $X_L = X_C$.

   H. Explain the correlations between triangles, vectors, and formulas.

   I. Give test.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency masters

      1. TM #1--Cosines and Power Factors

      2. TM #2--Trigonometric Functions Table

      3. TM #3--Series RCL Circuit

      4. TM #4--Triangles, Vectors, and Impedance Similarities

      5. TM #5--Resonant Frequency of Series RCL Circuits

      6. TM #6--Resonant Frequency of Parallel RCL Circuits

   E. Assignment sheets

      1. Assignment Sheet #1--Calculate Characteristics of a Series RCL Circuit

      2. Assignment Sheet #2--Calculate Characteristics of a Parallel RCL Circuit

SUGGESTED ACTIVITIES

3. Assignment Sheet #3--Determine Harmonic Frequencies

4. Assignment Sheet #4--Determine Characteristics of RCL Circuits with Varying Parameters

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1--Determine Resonant Frequency of a Series RCL Circuit

2. Job Sheet #2--Observe Effects of Series and Parallel Capacitors

H. Test

I. Answers to test

III. Unit references

A. Grob, Bernard. *Basic Electronics.* 4th ed. New York: McGraw-Hill Book Company, 1977.

B. *National Electrical Code.* Boston: National Fire Protection Association, 1980.

C. Seippel, Robert G. *Alternating Current Circuit Analysis.* Chicago: American Technical Society, 1975.

D. *Transformers and AC Circuits.* Unit 3, Plant Engineering Training Systems: Electrical Maintenance. Barrington, Illinois: Technical Publishing Co., 1975.

E. Zbar, Paul B., and Joseph G. Sloop. *Electricity-Electronics Fundamentals.* New York: Gregg Division of McGraw-Hill Book Company, 1977.

IMPEDANCE AND RESONANCE
UNIT IX

INFORMATION SHEET

I. Terms and definitions

   A. Impedance--Total restriction offered by a circuit, especially one operating on AC; combination of resistance and reactance

   B. Resonance--State or condition of a circuit when capacitive and inductive reactances cancel each other's effects at a particular frequency

   C. Resonant frequency--Frequency at which a circuit's reactive components cancel each other

   D. Reactance--Measure of a circuit; component's tendency to impede AC voltage and current changes

   E. Harmonic--Frequency having significance because it is a whole number (integer) multiple of a basic frequency and reacts to similar circuit characteristics

   F. Reactive power--Power needed by a circuit due to voltage and current phase displacement created by inductance and capacitance; also called *imaginary power* or *VARS*

   G. Vector--Arrow drawn in a relative direction and to a length representing magnitude

   H. Power factor--Measure of how well AC voltage and current are working in unison; cosine of the angle of displacement between AC voltage and current; ratio of actual power to apparent power

      (NOTE: Power factor is always 1 or less and is often expressed as a percentage.)

   I. Actual power--Power required by a circuit to do work, produce heat; also called *real power* or *true power*

   J. Apparent power--Total power needed by a circuit, including that which is due to voltage and current out-of-phase relationships

   K. Cosine--Fraction obtained by dividing the length of the side adjacent to an angle by the length of the hypotenuse of a right triangle

   L. Tuned circuit--Circuit consisting of inductance and capacitance which can be adjusted for resonance at the desired frequency

   M. Bandwidth--Width of the frequencies around resonance which have resonant effects

      EXAMPLE: A 10 kHz width

INFORMATION SHEET

N. Bandpass--Number in hertz of the area of bandwidth

EXAMPLE: From 95 kHz to 105 kHz

O. Admittance--Ease with which AC flows in a circuit; the reciprocal of impedance; expressed in mhos and symbolized **Y**

P. Susceptance--Reciprocal of reactance; measured in mhos

Q. Quality factor--Measure of sharpness of resonance or frequency selectivity of mechanical or electrical system

R. Selectivity--Ability to select narrow band of frequencies and reject all others; the higher the **Q**, the narrower the selectivity

S. Sensitivity--Ratio of minimum input signal required to create a desirable output; minimum input required for maximum output

T. Parameter--A constant, the value of which characterizes the behavior of one or more variables of a given system

II. Symbols and abbreviations associated with impedance and resonance

A. X_C--Capacitive reactance

B. X_L--Inductive reactance

C. **Z**--Impedance

D. F_r--Resonant frequency

E. √--Square root symbol

F. π--3.14

G. Ω--Ohm

H. **VAR**--Volt-amperes-reactive

I. **X**--Reactance

J. ϕ--Phase

K. <ϕ--Phase angle

L. P_f--Power factor

M. **Cos**--Cosine

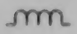
N. **RCL**--Resistance, capacitance, and inductance

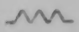
O. **L**--Inductance; inductor

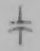
P. **C**--Capacitance; capacitor

INFORMATION SHEET

Q. R--Resistance; resistor

R.  --Circuit symbol for inductor

S.  --Circuit symbol for resistor

T.  --Circuit symbol for capacitor

U. Q--Quality factor

V. Bw--Bandwidth

W. Bp--Bandpass

X. R_g--Generator resistance

Y. →--Remains same

Z. ↑--Increases

AA. ↓--Decreases

III. Factors of impedance (Transparency #4)

A. Resistance

B. Capacitive reactance

C. Inductive reactance

IV. Phase relationships between voltage and current for each of the three factors of impedance

A. Resistance--Voltage and current are in phase

B. Capacitive reactance--Current is ahead of voltage by 90°

C. Inductive reactance--Current is behind voltage by 90°

V. Calculating impedance of series RCL circuits (Transparencies #3 and #4) Use the formula $Z = \sqrt{R^2 + (X_L - X_C)^2}$

(NOTE: The formula is merely a mathematical way of stating that the square of the hypotenuse [Z] is equal to the sum of the squares of the other two sides [R and $(X_L - X_C)$]. See transparency #4.)

INFORMATION SHEET

EXAMPLE: $R = 300\ \Omega$

$X_L = 200\ \Omega$

$X_C = 175\ \Omega$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{(300)^2 + (200 - 175)^2}$$

$$= \sqrt{(300)^2 + (25)^2}$$

$$= \sqrt{90{,}000 + 625}$$

$$= \sqrt{90{,}625}$$

$$= 301\ \Omega$$

(NOTE: Notice that Z is only slightly larger than R. Whichever is smaller [X_C or X_L] is always subtracted from the larger. The larger number determines the circuit function. The above circuit reacts inductively.)

VI. Calculating phase angle of a series RCL circuit (Transparencies #1 and #2; Assignment Sheet #1)

(NOTE: Phase angles in series RCL circuits are calculated as in series RC or RL circuits, using the cosine of the angle theta.)

$$\text{Cos} <\phi = \frac{\text{Adj}}{\text{Hyp}} \text{ or } \frac{R}{Z}$$

$$= \frac{300\ \Omega}{301\ \Omega}$$

= .9966 (Look up .9966 in the Trigonometric Functions Table in Transparency #2.)

$= 5^\circ <\phi$

VII. Calculating current and voltage in series RCL circuits

A. To find the total current in a series RCL circuit, use Ohm's Law

EXAMPLE: Impedance in the previous problem was 301 ohms, with a voltage applied of 602 volts

$$I_t = \frac{E_a}{R_t} \text{ or } \frac{E_a}{Z}$$

$$= \frac{602\ V}{301\ \Omega}$$

$$= 2\ A$$

(NOTE: In series circuits, circuit current remains the same throughout all components.)

INFORMATION SHEET

B. To find voltage, use Ohm's Law

EXAMPLE: $E_R = I_R \times R$

$= 2\text{ A} \times 300\ \Omega$

$= 600\text{ V}$

$E_L = I_L \times X_L$

$= 2\text{ A} \times 200\ \Omega$

$= 400\text{ V}$

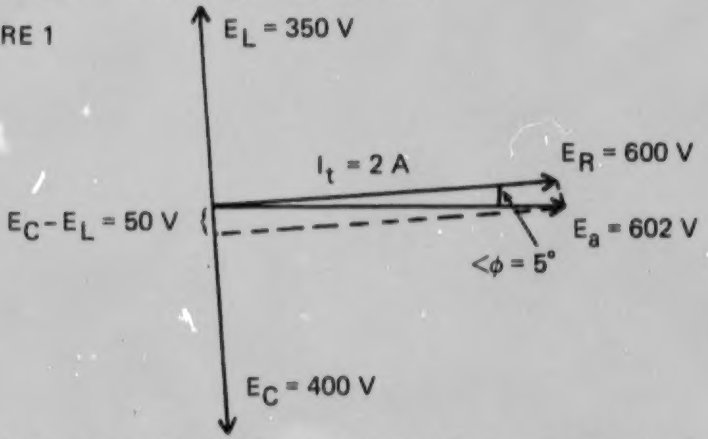
$E_C = I_C \times X_C$

$= 2\text{ A} \times 175\ \Omega$

$= 350\text{ V}$

(NOTE: The vector diagram [Figure 1] would then be a combination of the RC and RL vectors previously covered.)

FIGURE 1



C. To find the applied voltage, use the Pythagorean Theorem formula--

$E_a = \sqrt{E_R^2 + (E_C - E_L)^2}$

EXAMPLE: $E_a = \sqrt{E_R^2 + (E_C - E_L)^2}$

$= \sqrt{(600)^2 + (400 - 350)^2}$

$= \sqrt{(600)^2 + (50)^2}$

$= \sqrt{362{,}500}$

$= 602\text{ V}$

INFORMATION SHEET

VIII. Calculating power of series RCL circuits (Transparency #1)

(NOTE: Power in series RCL circuits is calculated as in series RC and RL circuits.)

A. Calculate for true power

EXAMPLE: The example has a current total of 2 amps and a resistive voltage of 600 volts (Figure 1)

$$P_t = E_R \times I_R$$

$$= 600 \text{ V} \times 2 \text{ A}$$

$$= 1200 \text{ W}$$

B. Calculate for apparent power

EXAMPLE: The example has a voltage applied of 602 volts and a current total of 2 amps (Figure 1)

$$P_a = E_a \times I_t$$

$$= 602 \text{ V} \times 2 \text{ A}$$

$$= 1204 \text{ VA}$$

C. Calculate for power factor

EXAMPLE: The example has a true power of 1200 watts and an apparent power of 1204 VA (Figure 1)

$$P_f = \frac{P_t}{P_a}$$

$$= \frac{1200 \text{ W}}{1204 \text{ VA}}$$

$$= .9966$$

IX. Calculating resonant frequency of series or parallel RCL circuits (Transparencies #5 and #6)--Use the formula $F_r = \frac{1}{2\pi\sqrt{LC}}$

EXAMPLE: $F_r = \frac{1}{2\pi\sqrt{LC}}$

L = 4 mH

C = 10 μF

$$F_r = \frac{1}{(2)\,(3.14)\sqrt{(4 \times 10^{-3})\,(10 \times 10^{-6})}}$$

$$= \frac{1}{6.28\sqrt{40 \times 10^{-9}}}$$

$$= \frac{1}{6.28\sqrt{4 \times 10^{-8}}}$$

INFORMATION SHEET

$$= \frac{1}{(6.28)\ (2 \times 10^{-4})}$$

$$= \frac{1}{12.56 \times 10^{-4}}$$

$$= \frac{1}{.001256}$$

$$= 796 \text{ Hz}$$

(NOTE: Any time the reactance value of C and L are equal, the circuit is said to be resonant. There will be only one frequency which will cause both X_C and X_L to be equal. At this point, impedance equals resistance or impedance is minimum, and current will then be maximum [Transparencies #5 and #6]. As frequency increases, X_L increases, and as frequency decreases, X_C increases. Thus, above resonance a circuit acts inductively, and below resonance a circuit acts capacitively.)

X. Determining quality factor ("Q") of a series circuit or parallel tank circuit, use the formula $Q = \frac{X_L}{R}$, or for parallel circuit $Q = \frac{R}{X_L}$

(NOTE: The "Q" of a circuit can be calculated only when the circuit is at resonance.)

EXAMPLE: A series RCL circuit has a resistance of 30 ohms and an inductive reactance of 300 ohms

$$Q = \frac{X_L}{R}$$

$$= \frac{300\,\Omega}{30\,\Omega}$$

$$= 10\,\Omega$$

(NOTE: A high quality factor is a ratio of 10 or more, a low quality factor is a ratio of less than 10 [Transparencies #5 and #6].)

XI. Determining bandwidth and bandpass of a series or parallel RCL circuit (Transparencies #5 and #6)

A. Bandwidth is the measurement of frequencies between the half power points of maximum current

EXAMPLE: In a series circuit, the resonant frequency is 10 kHz and the "Q" of the circuit is 10

$$Bw = \frac{F_r}{Q}$$

$$= \frac{10 \text{ kHz}}{10}$$

$$= 1 \text{ kHz}$$

B. Bandpass of a circuit is the actual frequencies at the upper and lower edges of the bandwidth area

EXAMPLE: Using the circuit in A, use the formula $Bp = F_r \pm \frac{Bw}{2}$

$$\begin{aligned} Bp &= F_r - \frac{Bw}{2} \\ &= 10\text{ kHz} - \frac{1\text{ kHz}}{2} \\ &= 10\text{ kHz} - .5\text{ kHz} \\ &= 9.5\text{ kHz (lower frequency)} \end{aligned}$$

$$\begin{aligned} Bp &= F_r + \frac{Bw}{2} \\ &= 10\text{ kHz} + \frac{1\text{ kHz}}{2} \\ &= 10\text{ kHz} + .5\text{ kHz} \\ &= 10.5\text{ kHz (upper frequency)} \end{aligned}$$

Bandpass = 9.5 to 10.5 kHz

XII. Calculating current in a parallel RCL circuit

(NOTE: Current in parallel RCL circuits is calculated in the same manner as in parallel RC or RL circuits.)

EXAMPLE: A circuit has a resistance of 30 ohms, a capacitive reactance of 18 ohms, an inductive reactance of 90 ohms, and a voltage of 180 volts

$$\begin{aligned} I_R &= \frac{E_R}{R} \\ &= \frac{180\text{ V}}{30\ \Omega} \\ &= 6\text{ A} \end{aligned}$$

$$\begin{aligned} I_C &= \frac{E_C}{X_C} \\ &= \frac{180\text{ V}}{18\ \Omega} \\ &= 10\text{ A} \end{aligned}$$

$$I_L = \frac{E_L}{X_L}$$

INFORMATION SHEET

$$= \frac{180\ V}{90\ \Omega}$$

$$= 2\ A$$

(NOTE: To find total current, use the formula $I_t = \sqrt{I_R^2 + (I_C - I_L)^2}$.)

EXAMPLE: $I_t = \sqrt{I_R^2 + (I_C - I_L)^2}$

$$= \sqrt{(6)^2 + (10 - 2)^2}$$

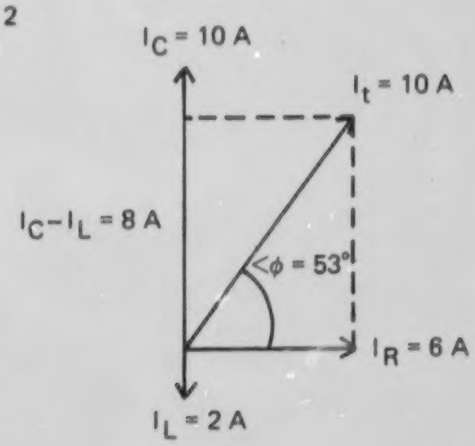
$$= \sqrt{36 + 64}$$

$$= \sqrt{100}$$

$$= 10\ A$$

(NOTE: The current vector would then be drawn as in Figure 2.)

FIGURE 2



XIII. Determining the phase angle of a parallel RCL circuit

$$\text{Cos} <\phi = \frac{\text{Adj}}{\text{Hyp}} \text{ or } \frac{I_R}{I_t}$$

$$= \frac{6\ A}{10\ A}$$

= .6 (Look up .6 in the Trigonometric Functions Table in Transparency #2.)

$= 53° <\phi$

XIV. Determining impedance of a parallel RCL circuit

(NOTE: To find total impedance, use Ohm's Law.)

INFORMATION SHEET

EXAMPLE: The previous circuit has a voltage of 180 volts and a total current of 10 amps

$$Z = \frac{E_a}{I_t}$$

$$= \frac{180\text{ V}}{10\text{ A}}$$

$$= 18\ \Omega$$

XV. Calculating power of parallel RCL circuits (Transparency #1)

(NOTE: Power in parallel RCL circuits is calculated as in parallel RC and RL circuits.)

A. Calculate true power in a circuit which has a resistor current of 6 amps and a resistor voltage of 180 volts

EXAMPLE: $P_t = E_R \times I_R$

$$= 180\text{ V} \times 6\text{ A}$$

$$= 1080\text{ W}$$

B. Calculate apparent power in a circuit which has an applied voltage of 180 volts and a total current of 10 amps

EXAMPLE: $P_a = E_a \times I_t$

$$= 180\text{ V} \times 10\text{ A}$$

$$= 1800\text{ VA}$$

C. Calculate power factor in a circuit which has a true power of 1080 watts and a power apparent of 1800 VA

EXAMPLE: $P_f = \frac{P_t}{P_a}$

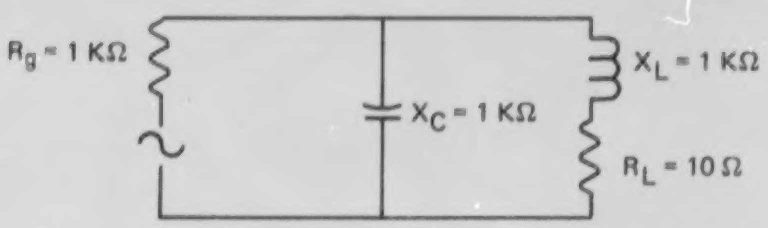
$$= \frac{1080\text{ W}}{1800\text{ VA}}$$

$$= .6$$

INFORMATION SHEET

XVI. Determining tank and circuit impedance of a parallel RCL circuit (Figure 3)

FIGURE 3



(NOTE: A parallel resonant circuit is called a *tank circuit*. This tank circuit will offer a high opposition or impedance to the generator. Line current then will be minimum and tank current maximum.)

A. Calculate tank impedance for the circuit in Figure 3

EXAMPLE: $Z \text{ tank} = \frac{X_L^2}{R_L}$

$= \frac{1000^2}{10}$

$= \frac{1{,}000{,}000}{10}$

= 100,000 Ω or 100 Kohms

B. Calculate circuit impedance for the circuit in Figure 3

EXAMPLE: Z circuit = R_g + Z tank

= 1 Kohm + 100 Kohms

= 101 Kohms

XVII. Determining harmonic frequencies (Assignment Sheet #3)--Multiply the fundamental frequency by integer numbers beginning with the number two

EXAMPLE: A circuit that oscillates at 400 hertz may also oscillate at 800 hertz (2 x 400); 1,200 hertz (3 x 400); or 1,600 hertz (4 x 400)

(NOTE: These higher frequencies are known as *harmonic frequencies*. If they appear at all, they will not appear as strong as the fundamental frequency. Those that do appear are generally weaker in amplitude as they are farther away from the fundamental frequency.)

INFORMATION SHEET

XVIII. Determining parameters of series and parallel RCL circuits (Assignment Sheet #4; Figures 4 and 5)

(NOTE: A parameter is a circuit constant such as voltage, resistance, or capacitance which affects other characteristics of a circuit such as current and capacitive reactance.)

A. In a series RCL circuit, applied voltage increases

FIGURE 4

	E_a	f	C	L	X_C	X_L	R	Z	I_t	E_R	E_C	E_L	P_a	P_t	ϕ	P_f
E_a ↑	↑	→	→	→	→	→	→	→	↑	↑	↑	↑	↑	↑	→	→

B. In a parallel RCL circuit, frequency increases

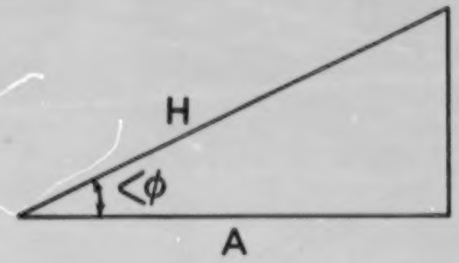
FIGURE 5

	E_a	f	C	L	X_C	X_L	R	Z	I_t	I_R	I_C	I_L	P_a	P_t	ϕ	P_f
f ↑	→	↑	→	→	↓	↑	→	↓	↑	→	↑	↓	↑	→	↑	↓

Cosines and Power Factors

Cosine Basic Definition

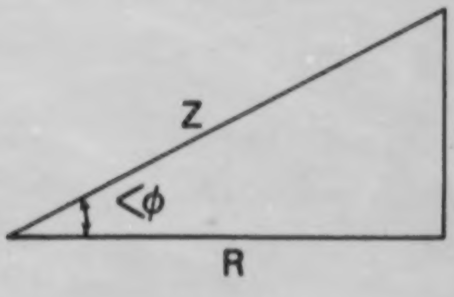
The cosine (COS) of the angle theta (ϕ) is the fraction obtained by dividing the adjacent side (A) by the hypotenuse (H).



$$\cos \phi = \frac{A}{H}$$

Power Factor Definition

The power factor (P_f) of a circuit is equal to the resistance (R) divided by the impedance (Z).



$$P_f = \frac{R}{Z}$$

Conclusion

The power factor (P_f) is equal to the cosine (COS) of the angle theta (ϕ) which is the phase angle.

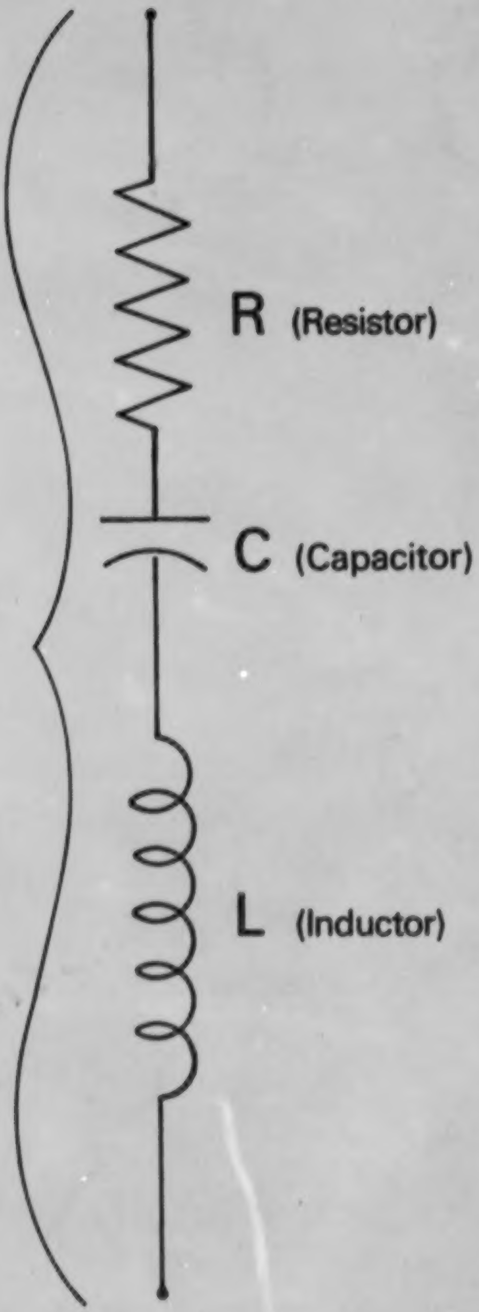
$$P_f = \cos \angle\phi$$

Trigonometric Functions Table

ANGLE	SIN	COS	TAN
0°	0.0000	1.0000	0.0000
1	.0175	.9998	.0175
2	.0349	.9994	.0349
3	.0523	.9986	.0524
4	.0698	.9976	.0699
5	.0872	.9962	.0875
6	.1045	.9945	.1051
7	.1219	.9925	.1228
8	.1392	.9903	.1405
9	.1564	.9877	.1548
10	.1736	.9848	.1763
11	.1908	.9816	.1944
12	.2079	.9781	.2126
13	.2250	.9744	.2309
14	.2419	.9703	.2493
15	.2588	.9659	.2679
16	.2756	.9613	.2867
17	.2924	.9563	.3057
18	.3090	.9511	.3249
19	.3256	.9455	.3443
20	.3420	.9397	.3640
21	.3584	.9336	.3839
22	.3746	.9272	.4040
23	.3907	.9205	.4245
24	.4067	.9135	.4452
25	.4226	.9063	.4663
26	.4384	.8988	.4877
27	.4540	.8911	.5095
28	.4695	.8829	.5317
29	.4848	.8746	.5543
30	.5000	.8660	.5774
31	.5150	.8572	.6009
32	.5299	.8480	.6249
33	.5446	.8387	.6494
34	.5592	.8290	.6745
35	.5736	.8192	.7002
36	.5878	.8090	.7265
37	.6018	.7986	.7536
38	.6157	.7880	.7813
39	.6293	.7771	.8098
40	.6428	.7660	.8391
41	.6561	.7547	.8693
42	.6691	.7431	.9004
43	.6820	.7314	.9325
44	.6947	.7193	.9657
45°	0.7071	0.7071	1.0000
46	.7193	.6947	1.0355
47	.7314	.6820	1.0724
48	.7431	.6691	1.1106
49	.7547	.6561	1.1504
50	.7660	.6428	1.1918
51	.7771	.6293	1.2349
52	.7880	.6157	1.2799
53	.7986	.6018	1.3270
54	.8090	.5878	1.3764
55	.8192	.5736	1.4281
56	.8290	.5592	1.4826
57	.8387	.5446	1.5399
58	.8480	.5299	1.6003
59	.8572	.5150	1.6643
60	.8660	.5000	1.7321
61	.8746	.4848	1.8040
62	.8829	.4695	1.8807
63	.8910	.4540	1.9626
64	.8988	.4384	2.0503
65	.9063	.4226	2.1445
66	.9135	.4067	2.2460
67	.9205	.3907	2.3559
68	.9272	.3746	2.4751
69	.9336	.3584	2.6051
70	.9397	.3420	2.7475
71	.9455	.3256	2.9042
72	.9511	.3090	3.0777
73	.9563	.2924	3.2709
74	.9613	.2756	3.4874
75	.9659	.2588	3.7321
76	.9703	.2419	4.0108
77	.9744	.2250	4.3315
78	.9781	.2079	4.7046
79	.9816	.1908	5.1446
80	.9848	.1736	5.6713
81	.9877	.1564	6.3138
82	.9903	.1392	7.1154
83	.9925	.1219	8.1443
84	.9945	.1045	9.5144
85	.9962	.0872	11.43
86	.9976	.0698	14.30
87	.9986	.0523	19.08
88	.9994	.0349	28.64
89	.9998	.0175	57.29
90	1.0000	.0000	—

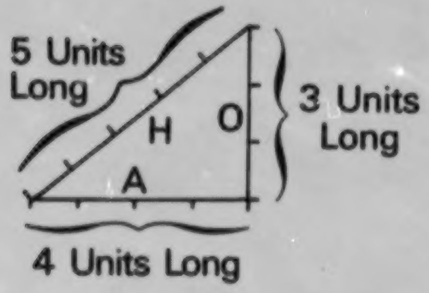
Series RCL Circuit

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

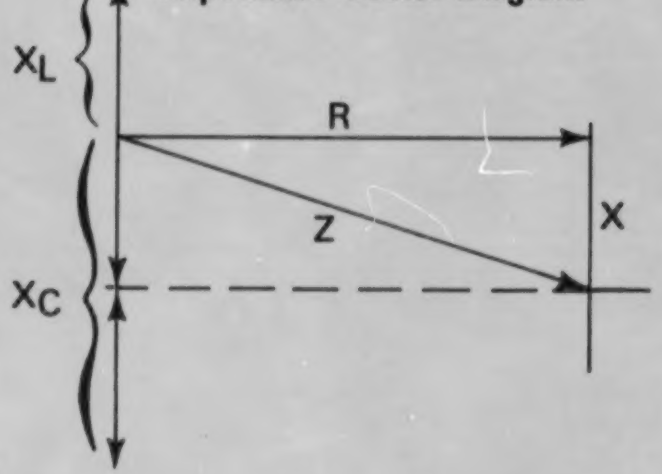

R (Resistor)
C (Capacitor)
L (Inductor)

Triangles, Vectors, and Impedance Similarities

Right Triangle

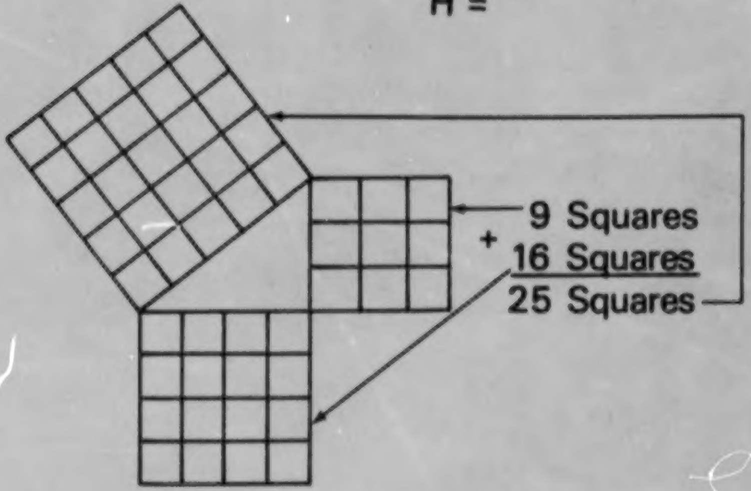

5 Units Long
H
O
A
3 Units Long
4 Units Long

Impedance Vector Diagram



Basic Theorem:

$$H^2 = A^2 + O^2 \quad \text{or} \quad H = \sqrt{A^2 + O^2}$$


9 Squares
+ 16 Squares
25 Squares

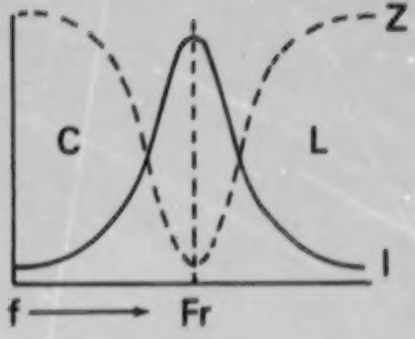
Impedance Formula:

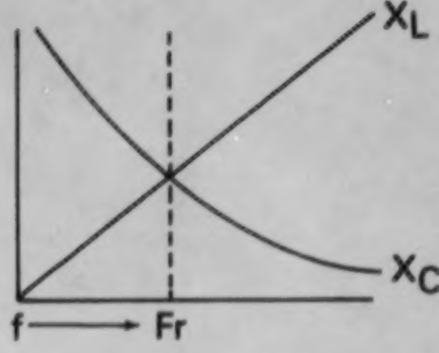
$$Z = \sqrt{R^2 + X^2}$$

or

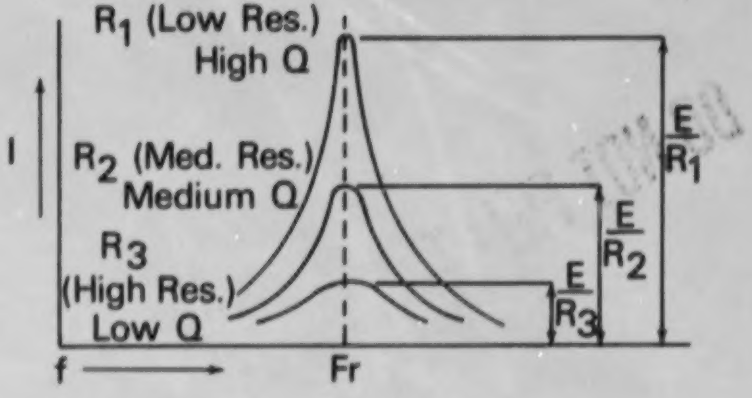
$$Z = \sqrt{R^2 + (X_C - X_L)^2}$$

Resonant Frequency of Series RCL Circuits



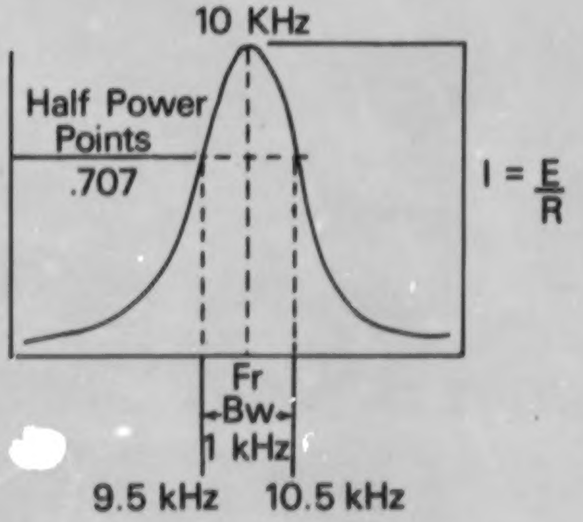


Q of Series RCL or Parallel RCL Tank

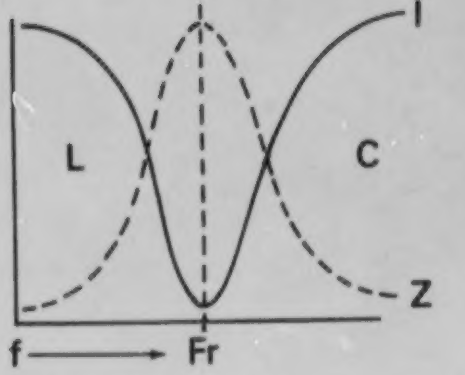


Bw = Width of Area

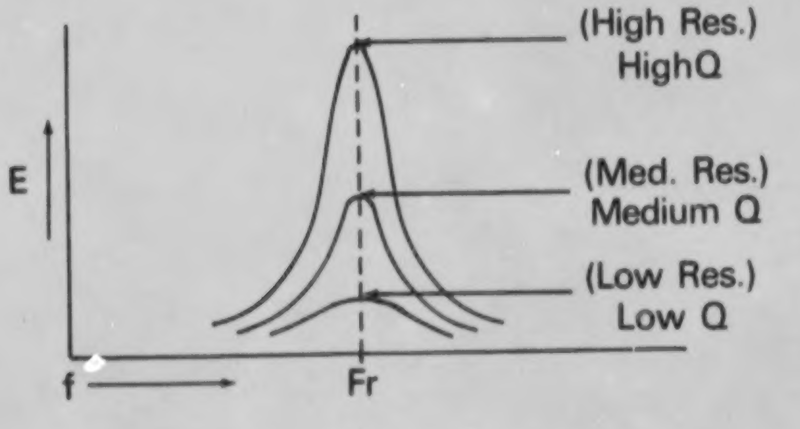
Bp = From One Frequency to Another



Resonant Frequency of Parallel RCL Circuits



Circuit Q of Parallel RCL Circuit



IMPEDANCE AND RESONANCE
UNIT IX

ASSIGNMENT SHEET #1–CALCULATE CHARACTERISTICS OF A SERIES RCL CIRCUIT

NAME ____________________ SCORE ____________

Parameters of a circuit determine how the circuit should function. A technician must be familiar with these characteristics in order to be able to work on and repair various types of equipment.

Determine how the following parameters will affect a series RCL circuit. Write your answers in the spaces provided. Use the Trigonometric Functions Table in Transparency #2 to determine phase angle.

A. A circuit has a resistance of 60 ohms, a capacitive reactance of 125 ohms, and an inductive reactance of 100 ohms. What is the impedance of this circuit?

$Z =$ ____________________

B. What is the current of the circuit if the applied voltage is 260 volts?

$I =$ ____________________

C. Determine the phase angle in the circuit.

$<\phi =$ ____________________

ASSIGNMENT SHEET #1

D. Draw an impedance vector.

E. Determine the voltage drop across each component in the circuit. Then draw a voltage vector.

1. E_R = ________________________
2. E_C = ________________________
3. E_L = ________________________

ASSIGNMENT SHEET #1

F. From your calculations in E, determine true power, apparent power, and power factor.

1. P_t = ____________________
2. P_a = ____________________
3. P_f = ____________________

G. If the value of the capacitor in F is 270 microfarads, the inductor is 300 millihenries, and the resistance is 60 ohms, determine resonant frequency.

F_r = ____________________

H. Using your calculated circuit characteristics, determine quality factor, bandwidth, and bandpass.

1. Q = ____________________
2. Bw = ____________________
3. Bp = ____________________ to ____________________

IMPEDANCE AND RESONANCE
UNIT IX

ASSIGNMENT SHEET #2–CALCULATE CHARACTERISTICS OF A PARALLEL RCL CIRCUIT

NAME ______________________ SCORE ____________

Parameters of a circuit are very useful when determining problems concerning parallel or series-parallel circuits.

Determine how the following parameters will affect a parallel RCL circuit. Write your answers in the spaces provided.

A. A circuit has a resistance of 5 ohms, a capacitive reactance of 3 ohms, an inductive reactance of 15 ohms, and a voltage applied of 60 volts. Calculate for individual currents, and then draw a current vector.

1. I_R = ____________________
2. I_C = ____________________
3. I_L = ____________________
4. I_t = ____________________

ASSIGNMENT SHEET #2

B. Determine the phase angle of the current vector you have drawn.

(NOTE: Use the Trigonometric Functions Table in Transparency #2.)

$<\phi =$ ______________________________

C. Calculate impedance in the circuit you have drawn.

Z = ______________________________

D. Use your calculations to find true power, apparent power, and power factor.

1. $P_t =$ ____________________
2. $P_a =$ ____________________
3. $P_f =$ ____________________

E. Capacitance in the circuit is 30 microfarads, and inductance is 33.5 millihenries. What is the resonant frequency?

$F_r =$ ______________________________

F. A resonant circuit has a capacitive reactance of 10 Kohms, a load resistance of 5 ohms, and a generator resistance of 50 Kohms. Calculate tank and circuit impedance.

1. Z tank = ______________________________
2. Z circuit = ______________________________

IMPEDANCE AND RESONANCE
UNIT IX

ASSIGNMENT SHEET #3--DETERMINE HARMONIC FREQUENCIES

NAME ______________________________ SCORE ______________

Circuits that react to AC frequencies by oscillating, also react to harmonics of the "fundamental" frequency. If a circuit will oscillate to a frequency of 60 hertz, it will probably also oscillate to a frequency of 120 hertz or 180 hertz. If a certain circuit was found to oscillate at 450 hertz, which other frequencies listed below might also excite the circuit into oscillations?

__________________ A. 1,350 Hz

__________________ B. 1,800 Hz

__________________ C. 2,150 Hz

__________________ D. 750 Hz

__________________ E. 900 Hz

__________________ F. 4,500 Hz

(NOTE: See if the frequencies are divisible by the fundamental frequency an integer number of times.)

IMPEDANCE AND RESONANCE
UNIT IX

ASSIGNMENT SHEET #4--DETERMINE CHARACTERISTICS OF RCL CIRCUITS WITH VARYING PARAMETERS

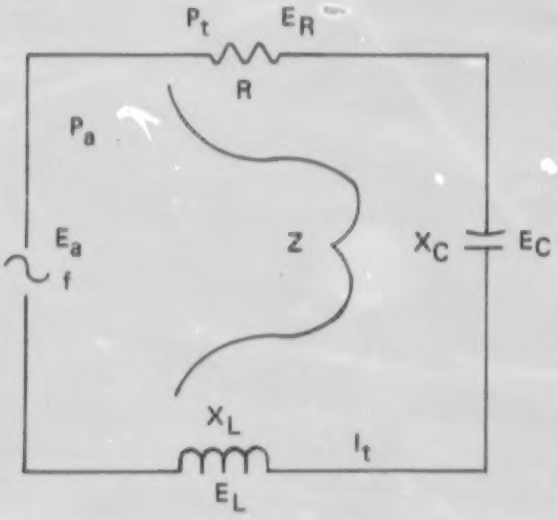
NAME ______________________________ SCORE ______________

Determine characteristics of RCL circuits with varying parameters. Complete the chart below, using the circuit in Figure 7.

FIGURE 6

	E_a	f	C	L	X_C	X_L	R	Z	I_t	E_R	E_C	E_L	P_a	P_t	P_f	ϕ
f ↓					5 K	8 K	3 K									
C ↑					12 K	18 K	5 K									
E_C ↑																
R ↓																
L ↓					10 K	6 K	3 K									

FIGURE 7



Resistance and Reactive Values Before Parameter Change

IMPEDANCE AND RESONANCE
UNIT IX

ANSWERS TO ASSIGNMENT SHEETS

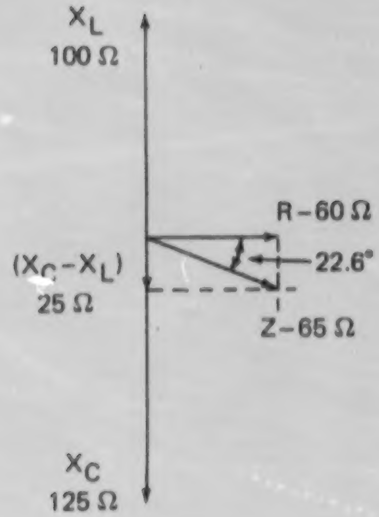
Assignment Sheet #1

A. 65 Ω

B. 4 A

C. 22.6°

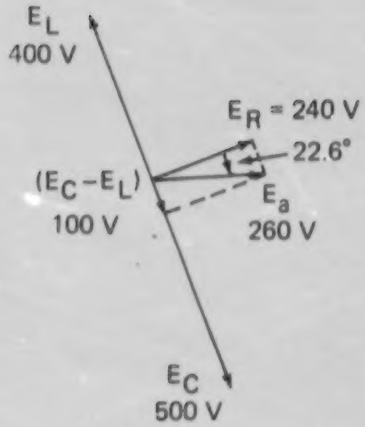
D.


X_L
100 Ω
R-60 Ω
(X_C-X_L)
25 Ω
22.6°
Z-65 Ω
X_C
125 Ω

E. 1. 240 V

2. 500 V

3. 400 V


E_L
400 V
E_R = 240 V
22.6°
(E_C-E_L)
100 V
E_a
260 V
E_C
500 V

ANSWERS TO ASSIGNMENT SHEETS

F. 1. 960 W

2. 1040 VA

3. .9231

G. 17.69 Hz

H. 1. .55

2. 32 Hz

3. 1.69 to 33.69 Hz

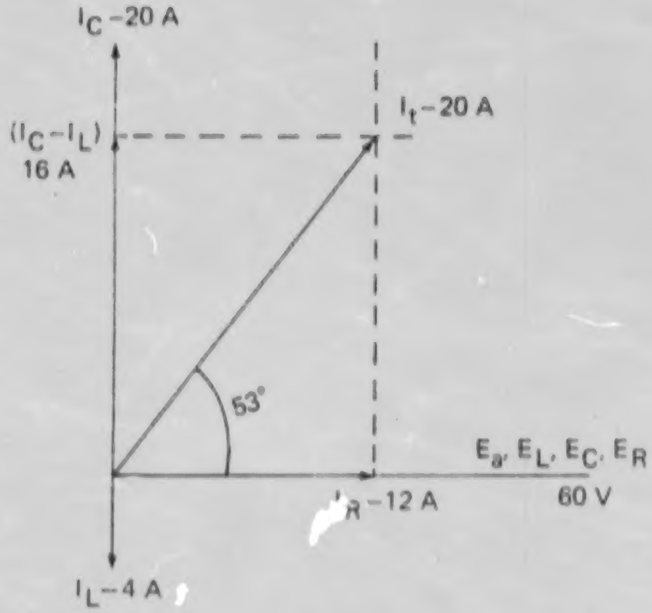
Assignment Sheet #2

A. 1. 12 A

2. 20 A

3. 4 A

4. 20 A



I_C – 20 A
I_t – 20 A
$(I_C - I_L)$ 16 A
53°
E_a, E_L, E_C, E_R
60 V
I_R – 12 A
I_L – 4 A

B. 53°

C. 3 Ω

ANSWERS TO ASSIGNMENT SHEETS

D. 1. 720 W
   2. 1200 VA
   3. .6

E. 158.84 Hz

F. 1. 20 MΩ
   2. 20.05 MΩ

Assignment Sheet #3

A. 1,350 Hz (3rd harmonic)

B. 1,800 Hz (4th harmonic)

C. No

D. No

E. 900 Hz (2nd harmonic)

F. 4,500 Hz (10th harmonic)

Assignment Sheet #4

	E_a	f	C	L	X_C	X_L	R	Z	I_t	E_R	E_C	E_L	P_a	P_t	P_f	ϕ
f ↓	→	↓	→	→	5 K ↑	8 K ↓	3 K →	↓	↑	↑	↑	▨	↑	↑	↑	↓
C ↑	→	→	↑	→	12 K ↓	18 K →	5 K →	↑	↓	↓	↓	↓	↓	↓	↓	↑
E_C ↑	↑	→	→	→	→	→	→	→	↑	↑	↑	↑	↑	↑	→	→
R ↓	→	→	→	→	→	→	↓	↓	↑	▨	↑	↑	↑	▨	↓	↑
L ↓	→	→	→	↓	10 K →	6 K ↓	3 K →	↑	↓	↓	↓	↓	↓	↓	↓	↑

IMPEDANCE AND RESONANCE
UNIT IX

JOB SHEET #1--DETERMINE RESONANT FREQUENCY OF A SERIES RCL CIRCUIT

I. Equipment and materials

- A. Multimeter
- B. Frequency oscillator--Range to 10 kilohertz or more
- C. Capacitor--From 40 to 50 microfarads
- D. Inductor--From .2 to .4 henries
- E. Resistor--From 50 to 500 ohms, fixed, 1/2 to 1 watt
- F. Test leads

II. Procedure

- A. Connect oscillator (signal or function generator), capacitor, inductor, and resistor in series
- B. Connect multimeter in parallel with the resistor
- C. Set multimeter to measure in the millivolt range of about 200 millivolts full-scale AC

  (NOTE: The range setting of step C will depend on the output capability of the oscillator and the specific range of the meter being used.)
- D. Turn oscillator output down
- E. Turn on oscillator
- F. Adjust frequency to about 20 hertz
- G. Turn up oscillator output until millivolt indication is observed on multimeter
- H. Slowly increase the frequency until multimeter indication peaks, then starts declining; change meter scales or oscillator output, if necessary
- I. Vary frequency range high and low until the peak point, as observed on the voltmeter, is identified
- J. Record the frequency

  f = ______________________________

JOB SHEET #1

K. Calculate the resonant frequency of the above capacitor and inductor

L. Record the result

F_r = ______________________________

(NOTE: Show your results to the instructor. If the observed frequency is somewhere near a harmonic of the calculated frequency, repeat the procedure. Tune the oscillator around the calculated frequency.)

M. Put equipment and materials away

IMPEDANCE AND RESONANCE
UNIT IX

JOB SHEET #2--OBSERVE EFFECTS OF SERIES AND PARALLEL CAPACITORS

I. Equipment and materials

A. Oscilloscope

B. Signal generator--Output frequency from VLF to 100 kHz

C. Capacitors--2, any type, fixed, from .1 to 10 μF and rated at least 20 volts

D. Inductor (RF Choke)--From 4 mH to 50 mH

E. Resistor--From 1/4 to 1 W, fixed, from 2 to 10 Kohms

F. Test leads

G. Scope probe

II. Procedure

A. Connect the resistor, inductor, and one capacitor in series so that the resistor is on one end of circuit

B. Connect the free end of the resistor to the common or ground connection of the signal generator

(NOTE: If the two output connections are not identified, ask your instructor if either one is grounded.)

C. Connect the opposite end of the series circuit to the other signal generator output

D. Connect the oscilloscope probe across the resistor, allowing the scope to view the signal waveform across the resistor

(NOTE: Certain signal generators may have an isolated output, in which case a particular grounded output terminal will not exist. In this situation, connect as if either terminal was the grounded terminal.)

E. Turn on the oscilloscope and allow it to warm up

F. Set oscilloscope to monitor a signal of about 12 volts peak-to-peak in the milliseconds sweep range

JOB SHEET #2

G. Adjust the sig-gen frequency to about 10 kilohertz

H. Tune the oscilloscope for a concentrated display of waveforms

(NOTE: Amplitude will be the observed parameter.)

I. Adjust the sig-gen output across several ranges from a few hundred hertz to several tens of kilohertz while observing the oscilloscope presentation for the resonent frequency

(NOTE: At certain frequencies the presentation on the oscilloscope will become high in amplitude but will decrease above and below these frequencies. Note these frequencies, and find the one that is the highest amplitude. This represents what is called the *resonant frequency*.)

J. Record this reading

F_{r_1} = ______________ hertz, with a single capacitor

K. Now connect both capacitors end to end, and repeat step I

L. Record this reading

F_{r_2} = ______________ hertz, with two capacitors in series

M. Connect both capacitors side by side and repeat step I

N. Record this reading

F_{r_3} = ______________ hertz, with two capacitors in parallel

(NOTE: As capacitance increases, the resonant frequency will decrease and vice versa.)

O. Which arrangement has the highest resonant frequency? ________________

Why? ____

P. Which arrangement has the lowest frequency? ______________________

Why? ____

(NOTE: Show your results to your instructor.)

Q. Put equipment and materials away

IMPEDANCE AND RESONANCE
UNIT IX

TEST

NAME ________________________________ SCORE ______________

1. Match terms associated with impedance and resonance to their correct definitions. Write the correct numbers in the blanks.

_____a. Ratio of minimum input signal required to create a desirable output; minimum input required for maximum output

_____b. State or condition of a circuit when capacitive and inductive reactances cancel each other's effects at a particular frequency

_____c. Power needed by a circuit due to voltage and current phase displacement created by inductance and capacitance; also called *imaginary power* or *VARS*

_____d. Fraction obtained by dividing the length of the side adjacent to an angle by the length of the hypotenuse of a right triangle

_____e. Frequency at which a circuit's reactive components cancel each other

_____f. Measure of how well AC voltage and current are working in unison; cosine of the angle of displacement between AC voltage and current; ratio of actual power to apparent power

_____g. Circuit consisting of inductance and capacitance which can be adjusted for resonance at the desired frequency

_____h. Total restriction offered by a circuit, especially one operating on AC; combination of resistance and reactance

_____i. Total power needed by a circuit, including that which is due to voltage and current out-of-phase relationships

_____j. Arrow drawn in a relative direction and to a length representing magnitude

_____k. A constant, the value of which characterizes the behavior of one or more variables of a given system

1. Impedance
2. Resonance
3. Resonant frequency
4. Tuned circuit
5. Sensitivity
6. Reactive power
7. Vector
8. Power factor
9. Parameter
10. Apparent power
11. Cosine

TEST

______l. Frequency having significance because it is a whole number (integer) multiple of a basic frequency and reacts to similar circuit characteristics

______m. Ease with which AC flows in a circuit; the reciprocal of impedance; expressed in mhos and symbolized **Y**

______n. Measure of sharpness of resonance or frequency selectivity of mechanical or electrical system

______o. Number in hertz of the area of bandwidth

______p. Measure of a circuit; component's tendency to impede AC voltage and current changes

______q. Power required by a circuit to do work, produce heat; also called *real power* or *true power*

______r. Width of the frequencies around resonance which have resonant effects

______s. Reciprocal of reactance; measured in mhos

______t. Ability to select narrow band of frequencies and reject all others; the higher the **Q**, the narrower the selectivity

12. Reactance
13. Bandwidth
14. Bandpass
15. Admittance
16. Susceptance
17. Quality factor
18. Selectivity
19. Harmonic
20. Actual power

2. Match symbols and abbreviations associated with impedance and resonance to their correct definitions. Write the correct numbers in the blanks.

______a. Inductive reactance

______b. Impedance

______c. Bandwidth

______d. Resonant frequency

______e. 3.14

______f. Square root symbol

______g. Phase angle

______h. Reactance

______i. Capacitive reactance

______j. Quality factor

1. X_C
2. X_L
3. Z
4. F_r
5. √
6. π
7. Bw
8. Q
9. X
10. <φ

TEST

______k. Ohm

______l. Volt-amperes-reactive

______m. Resistance; resistor

______n. Power factor

______o. Capacitance; capacitor

______p. Remains same

______q. Increases

______r. Decreases

______s. Cosine

______t. Resistance, capacitance, and inductance

______u. Bandpass

______v. Inductance; inductor

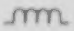
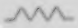
______w. Circuit symbol for capacitor

______x. Circuit symbol for inductor

______y. Circuit symbol for resistor

______z. Generator resistance

______aa. Phase

11. P_f
12. Cos
13. RCL
14. L
15. C
16. ϕ
17. R
18. 
19.
20. →
21. 
22. ↑
23. VAR
24. ↓
25. Ω
26. Bp
27. R_g

3. Name the factors of impedance.

a. ______________________________

b. ______________________________

c. ______________________________

4. State phase relationships between voltage and current for each of the three factors of impedance.

a. ______________________________

____

b. ______________________________

____

c. ______________________________

____

TEST

5. Calculate impedance of a series RCL circuit. Resistance is 40 ohms, capacitive reactance is 30 ohms, and inductive reactance is 60 ohms.

   Z = ____

6. Calculate phase angle of the series RCL circuit in test question 5.

   (NOTE: See Trigonometric Functions Table at end of test.)

   $<\phi$ = ____

7. Calculate current and voltage of a series RCL circuit. Voltage applied is 300 volts, resistance is 60 ohms, capacitive reactance is 10 ohms, and inductive reactance is 90 ohms.

   Z = ____

   I_t = ____

   E_R = ____

   E_C = ____

   E_L = ____

8. Calculate power of a series RCL circuit. Calculate true power, apparent power, and power factor of the circuit described in test question 7.

   P_t ____

   P_a ____

   P_f ____

TEST

9. Calculate resonant frequency of a series RCL circuit. Inductance is 500 millihenries, capacitance is 8 microfarads, and voltage applied is 450 volts.

F_r = ______________________________

10. Determine the quality factor of the following series and parallel RCL circuits.

    a. A series RCL circuit has a voltage applied of 320 volts, a resistance of 10 Kohms, a capacitive reactance of 500 Kohms, and a current of 5 milliamps.

    Q = ______________________________

    b. A parallel RCL circuit has a resistance of 10 Kohms, an inductive reactance of 1000 ohms, and an impedance of 10 Kohms.

    Q = ______________________________

11. Determine bandwidth and bandpass of a parallel RCL circuit. Capacitance is 2 microfarads, inductance is 45 millihenries, and quality factor is 50.

Bw = ______________________________

Bp = ______________________________

12. Calculate current of a parallel RCL circuit. Voltage applied is 360 volts, resistance is 12 ohms, capacitive reactance is 15 ohms, and inductive reactance is 9 ohms.

I_R = ______________________________

I_C = ______________________________

I_L = ______________________________

I_t = ______________________________

TEST

13. Determine the phase angle of a parallel RCL circuit. Use the circuit described in test question 12.

(NOTE: See Trigonometric Functions Table at end of test.)

$<\phi$ = ______________________

14. Determine impedance of a parallel RCL circuit. Total current is 12 milliamps, resistance voltage is 36 volts, resistance is 10 Kohms, and inductive reactance is 24 Kohms.

Z = ______________________

15. Calculate power of a parallel RCL circuit. Calculate the true power, apparent power, and power factor. Voltage applied is 360 volts, total current is 12 amps, and resistance is 60 ohms.

P_t = ______________________

P_a = ______________________

P_f = ______________________

16. Determine tank impedance and circuit impedance of a parallel RCL circuit. Voltage applied is 400 volts, generator resistance is 50 Kohms, inductive reactance is 30 Kohms, capacitive reactance is 30 Kohms, and load resistance is 1 Kohm.

Z tank = ______________________

Z circuit = ______________________

17. Determine harmonic frequencies. Determine the first four harmonic frequencies of the fundamental frequency of 150 Hz.

First harmonic = ______________________

Second harmonic = ______________________

Third harmonic = ______________________

Fourth harmonic = ______________________

TEST

18. Determine parameters of a parallel RCL circuit. Indicate in the spaces provided whether the values increase, decrease, or remain the same. Assume that the frequency of the input voltage decreases, the capacitive reactance is originally 10 Kohms, and the inductive reactance is 8 Kohms.

(NOTE: See Trigonometric Functions Table at end of test.)

E_a = ____________________

C = ____________________

L = ____________________

X_C = ____________________

X_L = ____________________

R = ____________________

Z = ____________________

I_t = ____________________

I_R = ____________________

I_C = ____________________

I_L = ____________________

P_a = ____________________

P_t = ____________________

P_f = ____________________

$<\phi$ = ____________________

(NOTE: Test questions 19-22 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

19. Calculate characteristics of a series RCL circuit.

20. Calculate characteristics of a parallel RCL circuit.

21. Determine characteristics of RCL circuits with varying parameters.

22. Demonstrate the ability to

    a. Determine resonant frequency of a series RCL circuit.

    b. Observe effects of series and parallel capacitors.

TEST

TRIGONOMETRIC FUNCTIONS TABLE

ANGLE	SIN	COS	TAN	ANGLE	SIN	COS	TAN
0°	0.0000	1.0000	0.0000	45°	0.7071	0.7071	1.0000
1	.0175	.9998	.0175	46	.7193	.6947	1.0355
2	.0349	.9994	.0349	47	.7314	.6820	1.0724
3	.0523	.9986	.0524	48	.7431	.6691	1.1106
4	.0698	.9976	.0699	49	.7547	.6561	1.1504
5	.0872	.9962	.0875	50	.7660	.6428	1.1918
6	.1045	.9945	.1051	51	.7771	.6293	1.2349
7	.1219	.9925	.1228	52	.7880	.6157	1.2799
8	.1392	.9903	.1405	53	.7986	.6018	1.3270
9	.1564	.9877	.1548	54	.8090	.5878	1.3764
10	.1736	.9848	.1763	55	.8192	.5736	1.4281
11	.1908	.9816	.1944	56	.8290	.5592	1.4826
12	.2079	.9781	.2126	57	.8387	.5446	1.5399
13	.2250	.9744	.2309	58	.8480	.5299	1.6003
14	.2419	.9703	.2493	59	.8572	.5150	1.6643
15	.2588	.9659	.2679	60	.8660	.5000	1.7321
16	.2756	.9613	.2867	61	.8746	.4848	1.8040
17	.2924	.9563	.3057	62	.8829	.4695	1.8807
18	.3090	.9511	.3249	63	.8910	.4540	1.9626
19	.3256	.9455	.3443	64	.8988	.4384	2.0503
20	.3420	.9397	.3640	65	.9063	.4226	2.1445
21	.3584	.9336	.3839	66	.9135	.4067	2.2460
22	.3746	.9272	.4040	67	.9205	.3907	2.3559
23	.3907	.9205	.4245	68	.9272	.3746	2.4751
24	.4067	.9135	.4452	69	.9336	.3584	2.6051
25	.4226	.9063	.4663	70	.9397	.3420	2.7475
26	.4384	.8988	.4877	71	.9455	.3256	2.9042
27	.4540	.8911	.5095	72	.9511	.3090	3.0777
28	.4695	.8829	.5317	73	.9563	.2924	3.2709
29	.4848	.8746	.5543	74	.9613	.2756	3.4874
30	.5000	.8660	.5774	75	.9659	.2588	3.7321
31	.5150	.8572	.6009	76	.9703	.2419	4.0108
32	.5299	.8480	.6249	77	.9744	.2250	4.3315
33	.5446	.8387	.6494	78	.9781	.2079	4.7046
34	.5592	.8290	.6745	79	.9816	.1908	5.1446
35	.5736	.8192	.7002	80	.9848	.1736	5.6713
36	.5878	.8090	.7265	81	.9877	.1564	6.3138
37	.6018	.7986	.7536	82	.9903	.1392	7.1154
38	.6157	.7880	.7813	83	.9925	.1219	8.1443
39	.6293	.7771	.8098	84	.9945	.1045	9.5144
40	.6428	.7660	.8391	85	.9962	.0872	11.43
41	.6561	.7547	.8693	86	.9976	.0698	14.30
42	.6691	.7431	.9004	87	.9986	.0523	19.08
43	.6820	.7314	.9325	88	.9994	.0349	28.64
44	.6947	.7193	.9657	89	.9998	.0175	57.29
				90	1.0000	.0000	………

IMPEDANCE AND RESONANCE
UNIT IV

ANSWERS TO TEST

1. a. 5
   b. 2
   c. 6
   d. 11
   e. 3
   f. 8
   g. 4
   h. 1
   i. 10
   j. 7
   k. 9
   l. 19
   m. 15
   n. 17
   o. 14
   p. 12
   q. 20
   r. 13
   s. 16
   t. 18

2. a. 2
   b. 3
   c. 7
   d. 4
   e. 6
   f. 5
   g. 10
   h. 9
   i. 1
   j. 8
   k. 25
   l. 23
   m. 17
   n. 11
   o. 15
   p. 20
   q. 22
   r. 24
   s. 12
   t. 13
   u. 26
   v. 14
   w. 19
   x. 18
   y. 21
   z. 27
   aa. 16

3. a. Resistance
   b. Capacitive reactance
   c. Inductive reactance

4. a. Resistance--Voltage and current are in phase
   b. Capacitive reactance--Current is ahead of voltage by 90°
   c. Inductive reactance--Current is behind voltage by 90°

ANSWERS TO TEST

5. 50 Ω

6. 36.87°

7. 100 Ω

   3 A

   180 V

   30 V

   270 V

8. 540 W

   900 VA

   .6

9. 79.6 Hz

10. a. 50

    b. 10

11. 10.6 Hz

    525.5 to 536.1 Hz

12. 30 A

    24 A

    40 A

    34 A

13. 28.07°

14. 3 Kohms

15. 2160 W

    4320 VA

    .5

16. 900 Kohms

    950 Kohms

ANSWERS TO TEST

17. 300 Hz

    450 Hz

    600 Hz

    750 Hz

18. E_a = Remain the same

    C = Remain the same

    L = Remain the same

    X_C = Increase

    X_L = Decrease

    R = Remain the same

    Z = Decrease

    I_t = Increase

    I_R = Remain the same

    I_C = Decrease

    I_L = Increase

    P_a = Increase

    P_t = Remain the same

    P_f = Decrease

    $<\phi$ = Increase

19. Evaluated to satisfaction of instructor

20. Evaluated to satisfaction of instructor

21. Evaluated to satisfaction of instructor

22. Performance skills evaluated to satisfaction of instructor

BASIC WIRING TECHNIQUES
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to demonstrate the ability to wire a plug to a power cable, check a 120-volt receptacle for proper wiring, and crimp terminal connectors onto conductors. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with basic wiring techniques to their correct definitions.
2. Match symbols and abbreviations associated with basic wiring techniques to their correct interpretations.
3. Identify circuit symbols associated with basic wiring.
4. State power characteristics of an ordinary wall receptacle.
5. List industrial applications for a 120-volt, alternating current, single-phase, 60-hertz, 2-wire, with ground power source.
6. Distinguish between advantages and disadvantages of a 120-volt, alternating current, single-phase, 60-hertz, 2-wire, with ground power source.
7. Describe configurations of three-phase or polyphase power.
8. Name advantages of three-phase or polyphase power.
9. Match agencies and organizations that control electrical wiring practices to their correct activities.
10. Complete a chart of characteristics of a 120-volt, alternating current, single-phase, 60-hertz circuit.
11. Identify common crimp-type terminal connectors.
12. Identify terminals on 120-volt devices.
13. Diagram a distribution circuit.
14. Demonstrate the ability to
    a. Wire a plug to a power cable.
    b. Check a 120-volt receptacle for proper wiring.
    c. Crimp terminal connectors onto conductors.
    d. Wire a plug to a three-phase power cord.

BASIC WIRING TECHNIQUES
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Show an AC waveform on an oscilloscope screen by connecting the probe to a 120-volt receptacle.

   H. Show that ground and neutral connectors on a receptacle do not produce any voltage waveform on an oscilloscope screen.

   I. Using Transparencies #1-#5, explain the source of 120-volt, 60-hertz, single-phase power. Note that power originates from power companies as three-phase and a part of it is tapped for single-phase use.

   J. Using Transparency #4, explain how 120-volt circuits are wired in parallel, and point out the difference between neutral and ground.

   K. Using Transparency #2, show how circuit symbols relate to actual physical devices.

   L. Show examples of circuits as illustrated on Transparency #4.

   M. Give test.

II. Instructional materials

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM #1--120-Volt Devices

      2. TM #2--Comparing Circuit Symbols to Actual Equipment

      3. TM #3--Characteristics of a 120-Volt, Alternating Current, Single-Phase, 60-Hertz Circuit

SUGGESTED ACTIVITIES

4. TM #4--Typical Method of Supplying a 120-Volt, 60-Hertz, Single-Phase Circuit in Industry

5. TM #5--Polyphase Power Connections

D. Assignment sheets

1. Assignment Sheet #1--Identify Terminals on 120-Volt Devices

2. Assignment Sheet #2--Diagram a Distribution Circuit

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1--Wire a Plug to a Power Cable

2. Job Sheet #2--Check a 120-Volt Receptacle for Proper Wiring

3. Job Sheet #3--Crimp Terminal Connectors onto Conductors

4. Job Sheet #4--Wire a Plug to a Three-Phase Power Cord

G. Test

H. Answers to test

III. Unit references

A. Gebert, Kenneth L. and Kenneth R. Edwards. *Transformers*. 2nd ed. Chicago: American Technical Society, 1974.

B. *National Electrical Code*. Boston: National Fire Protection Association, 1980.

(NOTE: Students should have their own copies or have access to the latest edition of the *National Electrical Code*.)

BASIC WIRING TECHNIQUES
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Neutral conductor--Connects to earth ground, usually at transformer supplying power to building or circuit; operates at zero volts, but carries current between source of power and equipment being operated (Transparencies #1, #3, and #4)

B. Ground conductor--Connects electrical equipment directly to earth ground, but does not normally carry any current; operates at zero volts and carries current only if faults or short circuits occur (Transparencies #1 and #3)

(NOTE: A ground conductor may also be referred to as a *safety ground*.)

C. Hot conductor--Connects to power source; operates at the rated voltage; carries current (Transparencies #1, #3, and #4)

(NOTE: A hot conductor may also be referred to as a *live conductor* or *hot wire*.)

D. Earth ground--Connection or conductor terminated within the soil, usually through grounding rods driven into or buried in the ground near electrical equipment

E. Chassis ground--Connection or conductor terminated at a metal case or electrical equipment frame, which may or may not be connected to earth ground

F. Root-mean-square--Square root of the time average of the square of a quantity; value of AC voltage, current, or power which compares to the equivalent DC value for effectiveness; value of AC normally specified or understood; value of AC normally measured with meters

G. Electromagnet--Magnet that results from electricity passing through a coil of wire

H. Solenoid--Electromagnetic mechanism used from remote locations to open valves or to control mechanical latches

I. Relay--Electrical switch controlled by an electromagnet

J. Circuit breaker--Electromagnetic device that opens a circuit automatically when the current exceeds a predetermined value

K. Short circuit--Situation where electrical current takes an improper path; usually due to faults in insulation, contact between terminals of different voltages, or wiring errors

L. Polyphase--Electrical power generated such that the three armature windings have output voltages 120° out of phase with each other

INFORMATION SHEET

M. Single phase--Alternating current circuit with only two points of entry; points are in phase

II. Symbols and abbreviations associated with basic wiring techniques

A. **UL**--Underwriters Laboratories

B. **OSHA**--Occupational Safety and Health Administration

C. **NEMA**--National Electrical Manufacturers Association

D. **Hz**--Hertz

E. **ϕ**--Phase

F. **w/g**--With ground wire

G. **Cu**--Copper

H. **Al**--Aluminum

I. **N**--Neutral

J. **L**--Line

K. **G**--Ground

L. **F**--Fuse

M. **rms**--Root-mean-square

N. **AWG**--American Wire Gauge

O. **TB**--Terminal board

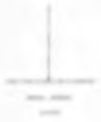
P. **AC**--Alternating current

Q. **DC**--Direct current

III. Circuit symbols (Transparency #2; Figures 1-10)

A. Earth ground--

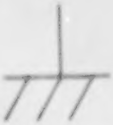
FIGURE 1



INFORMATION SHEET

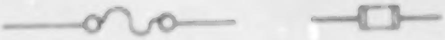
B. Chassis ground--

FIGURE 2



C. Fuse--

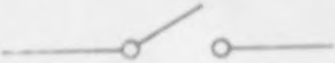
FIGURE 3



(NOTE: Both symbols are in common use.)

D. Switch--

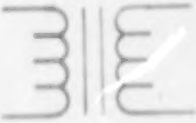
FIGURE 4



(NOTE: There are many types of switches; consequently there are many types of circuit symbols. These are covered in more depth in the unit on switches and relays.)

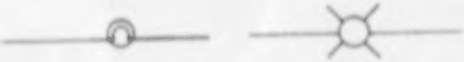
E. Transformer--

FIGURE 5



F. Lamp--

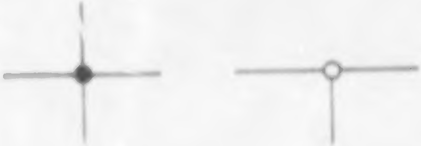
FIGURE 6



(NOTE: Both symbols are in common use.)

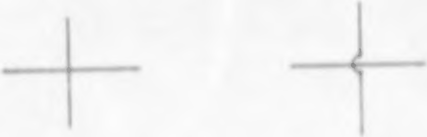
G. Connecting wires--

FIGURE 7



H. Wires crossing but not connecting--

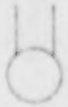
FIGURE 8



INFORMATION SHEET

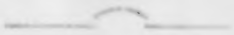
I. Single-phase AC motor – –

FIGURE 9



J. Circuit breaker – –

FIGURE 10



IV. Power characteristics of an ordinary wall receptacle (Transparency #1)

A. Voltage–120 volts, rms

B. Phase–Single

C. Frequency–60 hertz

D. Connection–Two wire with safety ground

(NOTE: An alternating current waveform actually peaks to about 170 volts, but since it is constantly changing, the effective value is not that of the peak or even that of the average value. Formulas for these various voltage comparisons and waveform diagrams can be found in the unit titled "Oscilloscope.")

V. Industrial applications for a 120-volt, alternating current, single-phase, 60-hertz, 2-wire, with ground power source

(NOTE: Equipment listed is often designed to operate at higher voltages, and some of the equipment listed is commonly designed for polyphase power.)

A. Small hand and shop tools

B. Wall clocks and time clocks

C. Lamps and light fixtures

D. Office equipment

E. Electronic test equipment

F. Laboratory equipment

G. Control wiring for systems

H. Small motors, fans, and pumps

INFORMATION SHEET

VI. Advantages and disadvantages of a 120-volt, alternating current, single-phase, 60-hertz, 2-wire, with ground power source

A. Advantages

1. Most small tools and appliances are designed to operate at this power
2. Common to homes, offices, schools, commercial buildings, and industrial plants
3. Most ordinary wires, switches, and electrical components are capable of operating safely at this power
4. Standard connectors, cables, and receptacles are economical and widely available
5. Voltage is sufficient for lengthy control wiring with numerous switches, solenoids, and relays
6. Voltage does not pose an unacceptable hazard in most applications, even though it can be deadly

B. Disadvantages

1. Equipment sizes are excessive for power applications
2. Power delivered--compared to the number and size of the wires--is not as efficient as with polyphase techniques
3. Sixty hertz is not as efficient for motors and transformers as higher frequencies, such as 400 hertz
4. Large currents required to furnish equivalent power can result in excessive line loss, voltage drop, and inefficiency
5. Large size of equipment can cost more than smaller, higher voltage equipment of the same power capability
6. Alternating current equipment, lighting apparatus, and cables can cause interference in sensitive test equipment and control systems
7. Industrial power distribution systems may not have 120-volt alternating current available unless extra transformers are installed
8. Reversing direction of rotation for single-phase, alternating current motors is more complex than for direct current or polyphase motors
9. Speed control of alternating current motors is more difficult than with direct current

INFORMATION SHEET

VII. Configurations of three-phase or polyphase power (Transparency #5)

A. Wye–Coils joined at one end; "Y" shaped

B. Delta–Coils hooked in series; triangular

VIII. Advantages of three-phase or polyphase power

A. Smaller machines than those used for single-phase

B. Simpler construction than that needed for single-phase

C. Better operating characteristics than single-phase

D. More efficient power distribution than that in single-phase

E. Self starting in AC induction motors

F. AC ripple easier to filter in DC power supplies

G. Two different voltages available

IX. Agencies and organizations that control electrical wiring practices

A. National Fire Protection Association–Publishes the *National Electrical Code*, a handbook of nationally accepted rules and procedures for electrical wiring

B. Underwriters Laboratories–Tests electrical equipment and apparatus for safety and dependability

C. Occupational Safety and Health Administration–Inspects plants and electrical equipment to ensure employee safety

(NOTE: Electrical equipment is only one of the many items inspected by OSHA.)

D. National Electrical Manufacturers Association–Sets standards for electrical equipment compatability

X. Characteristics of a 120-volt, alternating current, single-phase, 60-hertz circuit (Transparency #3; Assignment Sheet #2)

(NOTE: Codes and conditions specified by the chart on the following page are in accordance with the *National Electrical Code*. Specific exceptions to these characteristics exist under prescribed conditions.)

INFORMATION SHEET

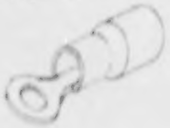
CHARACTERISTIC	CONDUCTOR		
	HOT WIRE	NEUTRAL WIRE	SAFETY GROUND
COLOR CODE OF WIRE	ALMOST ANY COLOR EXCEPT WHITE OR NATURAL GREY; USUALLY BLACK OR RED	WHITE OR NATURAL GREY AS REQUIRED BY THE *NATIONAL ELECTRICAL CODE*	GREEN, GREEN WITH YELLOW OR A WHITE STRIPE, OR BARE METAL AS REQUIRED BY THE *NATIONAL ELECTRICAL CODE*
CONDUCTION OF CURRENT	NORMALLY CARRIES CURRENT	NORMALLY CARRIES CURRENT	ONLY CARRIES CURRENT WHEN SHORT CIRCUITS OR FAULTS EXIST
OPERATING VOLTAGE	120 VOLTS AC AT 60 HERTZ	ZERO VOLTS	ZERO VOLTS
SWITCHES OR FUSES ALLOWED	SWITCHES AND FUSES ORDINARILY INTERRUPT THE CONTINUITY OF THIS CIRCUIT	NORMALLY SWITCHES AND FUSES ARE NOT ALLOWED	SWITCHES, FUSES, AND CIRCUIT INTERRUPTIONS ARE NOT ALLOWED
COLOR OF CONNECTING SCREW ON RECEPTACLES AND PLUGS	BRASS OR COPPER COLORED	CHROME OR SILVER COLORED	GREEN
LETTER DESIGNATOR	L	N	G

INFORMATION SHEET

XI. Common crimp-type terminal connectors (Figures 11-16)

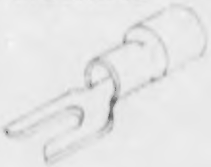
A. Ring tongue

FIGURE 11



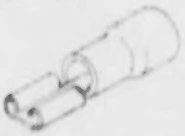
B. Spade tongue

FIGURE 12



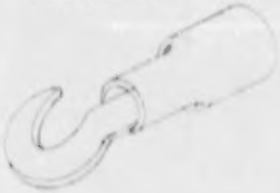
C. Quick disconnect

FIGURE 13



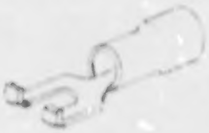
D. Hook tongue

FIGURE 14



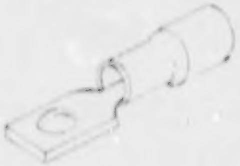
E. Flanged-tip spade tongue

FIGURE 15



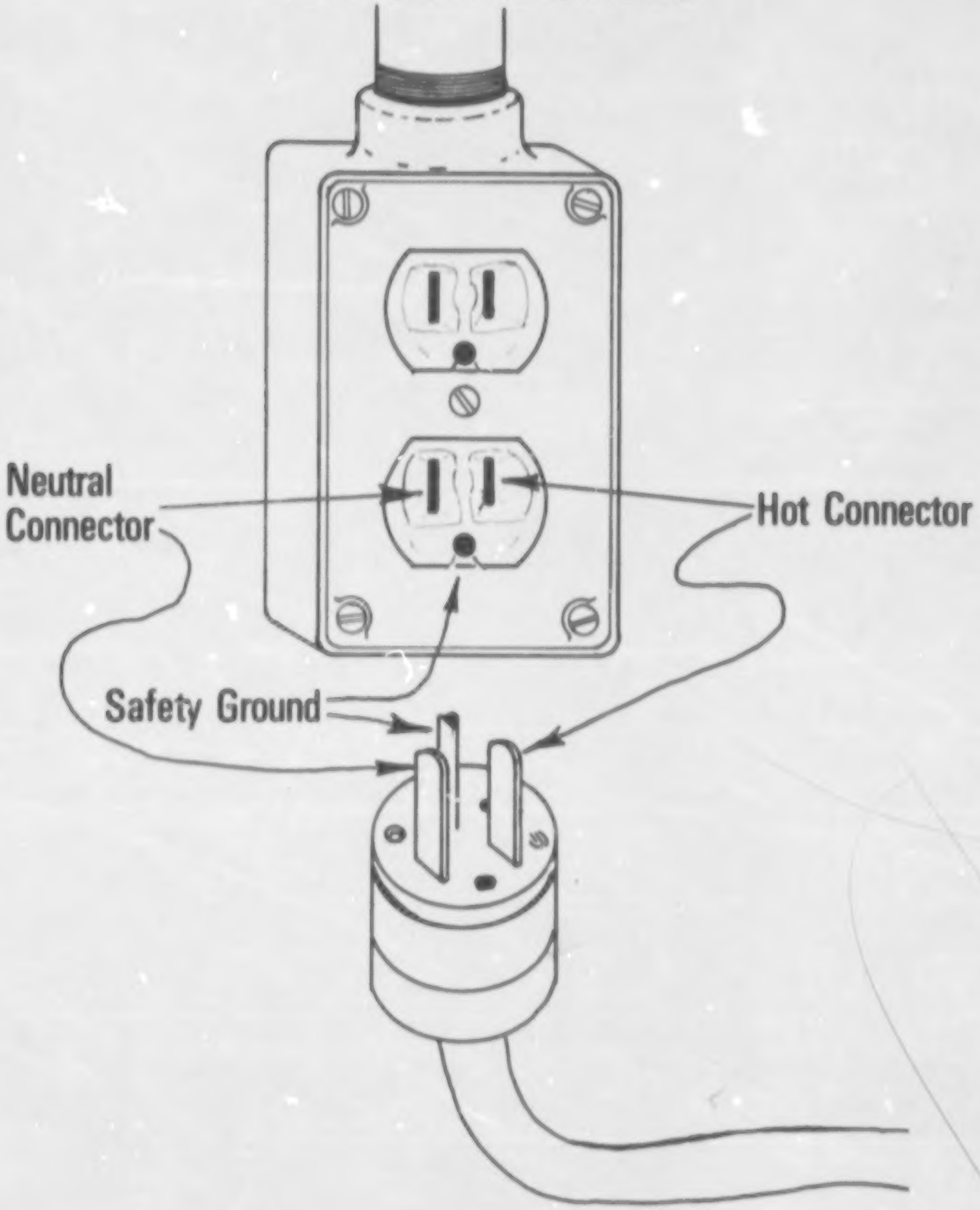
F. Block ring tongue

FIGURE 16



(NOTE: Each type of terminal connector has certain benefits. The ring tongue will not become disconnected merely because the screw is loose [as the spade tongue might], but to disconnect the ring tongue, the screw holding it must be completely removed. The quick disconnect is fast but does not provide an electrical connection as good as those held by screws. Block types do not work loose easily because their rectangular shape fits into the connection space on terminal boards, thus prohibiting the terminal from rotating. The flanged tip terminal does not disconnect from loose screws as may the ordinary spade tongue. For assembly and troubleshooting of some circuits, the hook tongue may work best. The technician can hook several hook tongue terminals onto a screw one at a time and not tighten the screw until all terminals are connected. There are many other types of terminal connectors with other characteristics.)

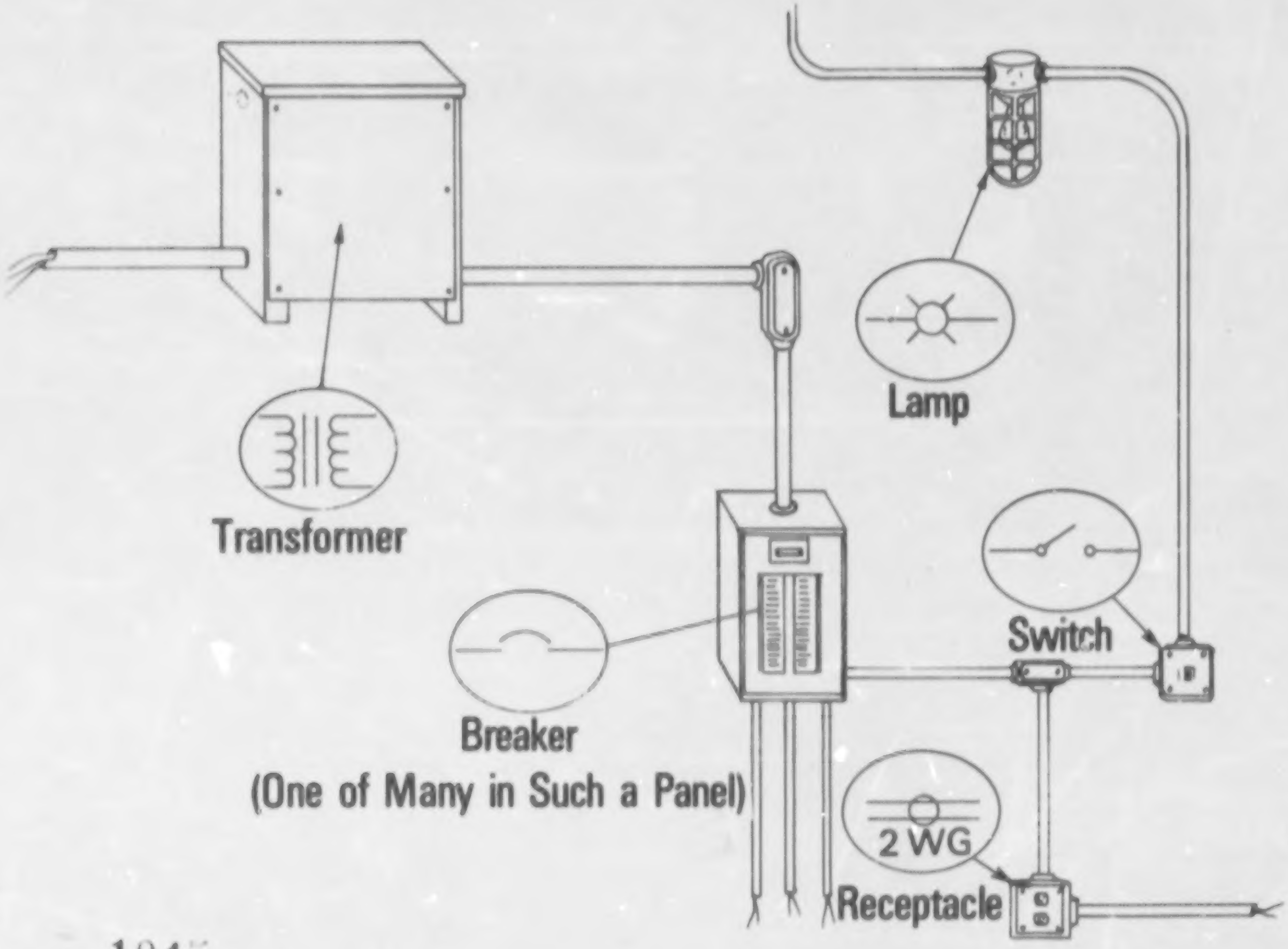
120-Volt Devices


Neutral Connector
Hot Connector
Safety Ground

120 Volts rms, Alternating Current,
60 Hertz, 2–Wire With Safety Ground
Duplex Receptacle and Power Cable

1044

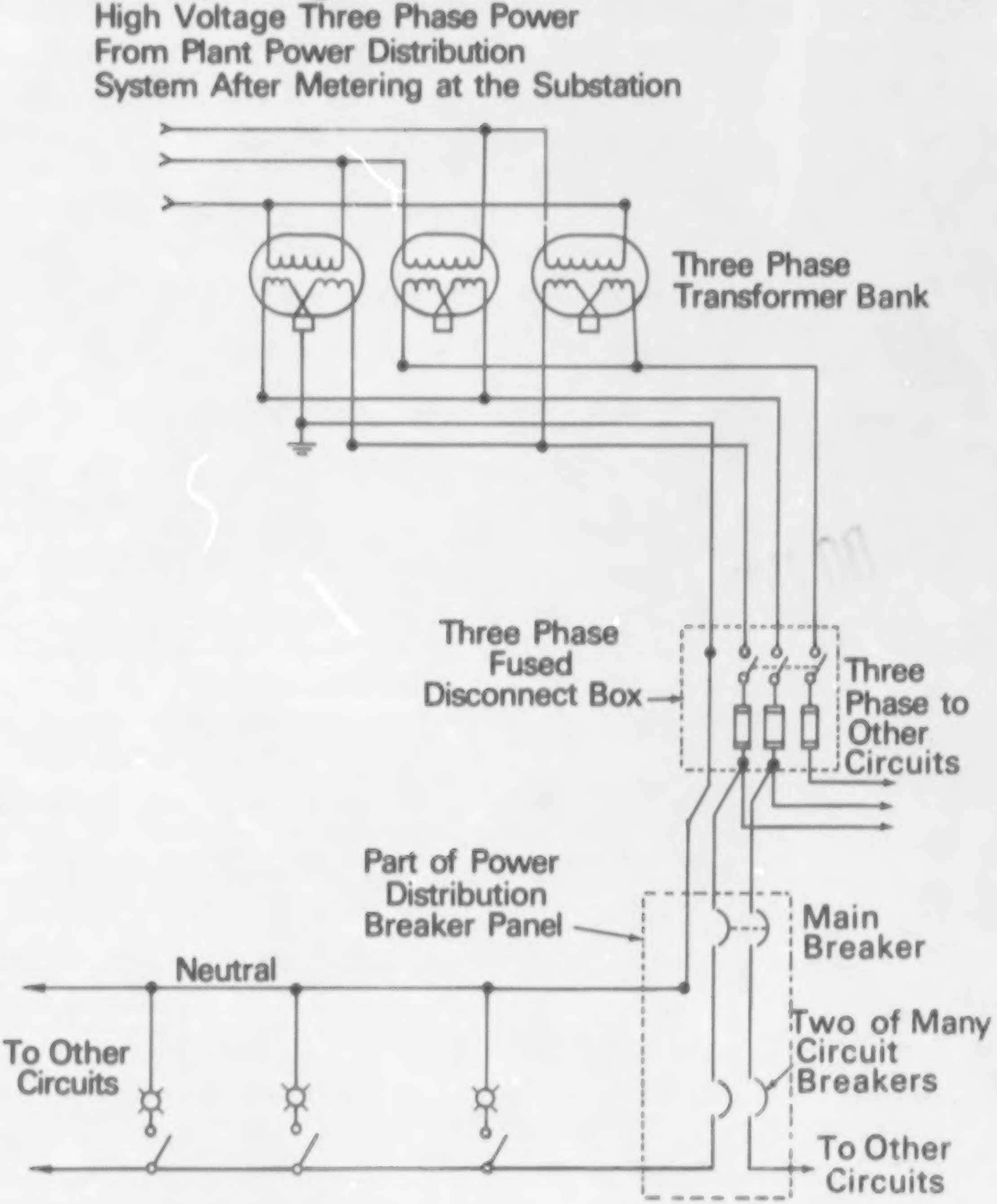
Comparing Circuit Symbols to Actual Equipment


Transformer
Lamp
Switch
Breaker
(One of Many in Such a Panel)
2 WG
Receptacle

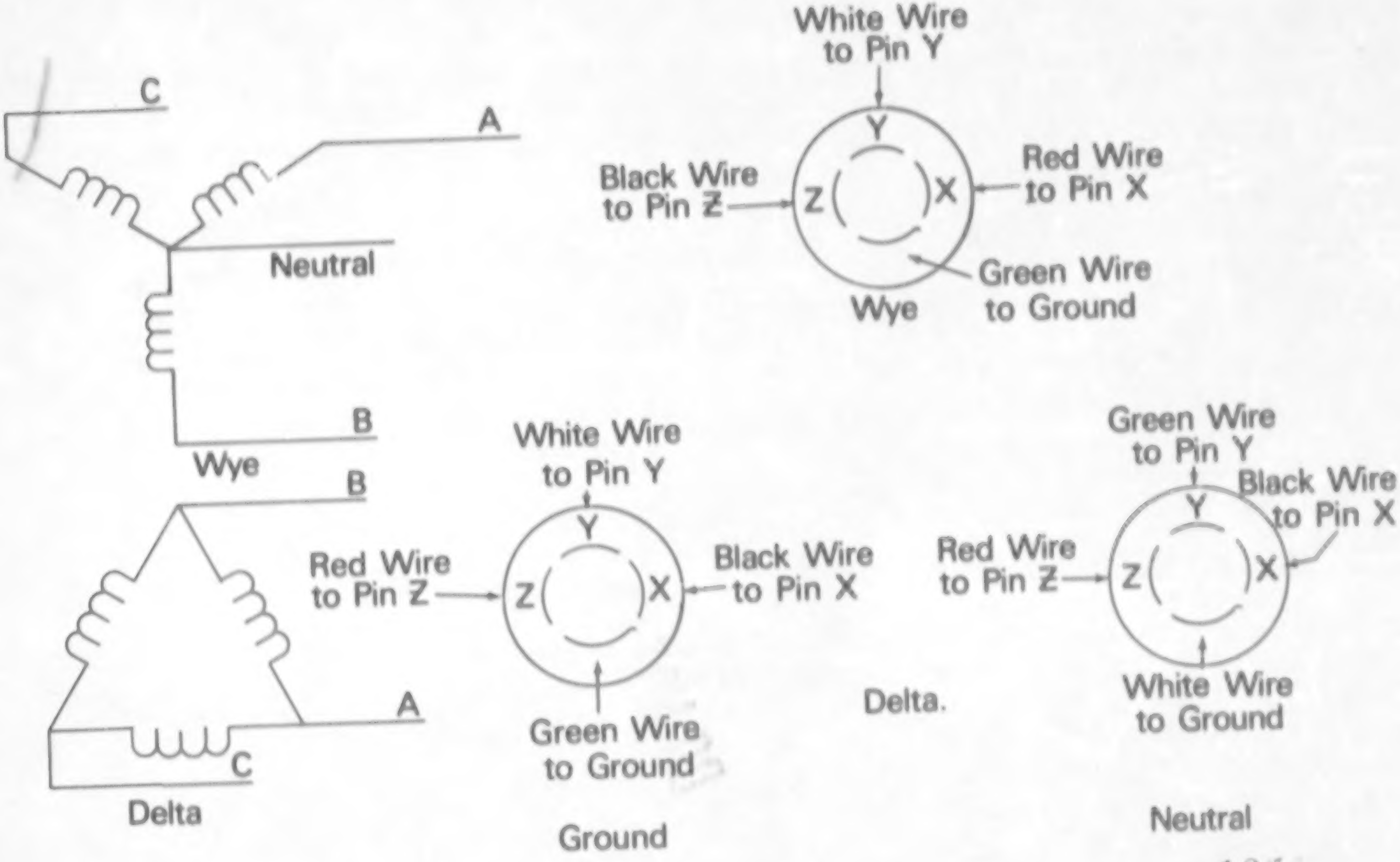
Characteristics of a 120-Volt, Alternating Current, Single-Phase, 60-Hertz Circuit

CHARACTERISTIC	CONDUCTOR		
	HOT WIRE	NEUTRAL WIRE	SAFETY GROUND
COLOR CODE OF WIRE	ALMOST ANY COLOR EXCEPT WHITE OR NATURAL GREY; USUALLY BLACK OR RED	WHITE OR NATURAL GREY AS REQUIRED BY THE *NATIONAL ELECTRICAL CODE*	GREEN, GREEN WITH YELLOW OR A WHITE STRIPE, OR BARE METAL AS REQUIRED BY THE *NATIONAL ELECTRICAL CODE*
CONDUCTION OF CURRENT	NORMALLY CARRIES CURRENT	NORMALLY CARRIES CURRENT	ONLY CARRIES CURRENT WHEN SHORT CIRCUITS OR FAULTS EXIST
OPERATING VOLTAGE	120 VOLTS AC AT 60 HERTZ	ZERO VOLTS	ZERO VOLTS
SWITCHES OR FUSES ALLOWED	SWITCHES AND FUSES ORDINARILY INTERRUPT THE CONTINUITY OF THIS CIRCUIT	NORMALLY SWITCHES AND FUSES ARE NOT ALLOWED	SWITCHES, FUSES, AND CIRCUIT INTERRUPTIONS ARE NOT ALLOWED
COLOR OF CONNECTING SCREW ON RECEPTACLES AND PLUGS	BRASS OR COPPER COLORED	CHROME OR SILVER COLORED	GREEN
LETTER DESIGNATOR	L	N	G

Typical Method of Supplying a 120-Volt, 60-Hertz, Single-Phase Circuit in Industry


High Voltage Three Phase Power
From Plant Power Distribution
System After Metering at the Substation
Three Phase Transformer Bank
Three Phase Fused Disconnect Box
Three Phase to Other Circuits
Part of Power Distribution Breaker Panel
Main Breaker
Neutral
Two of Many Circuit Breakers
To Other Circuits
To Other Circuits

Polyphase Power Connections


C
A
Neutral
B
Wye
White Wire to Pin Y
Y
Black Wire to Pin Z
Z
X
Red Wire to Pin X
Green Wire to Ground
Wye
B
A
C
Delta
White Wire to Pin Y
Y
Red Wire to Pin Z
Z
X
Black Wire to Pin X
Green Wire to Ground
Ground
Delta.
Green Wire to Pin Y
Y
Black Wire to Pin X
Red Wire to Pin Z
Z
X
White Wire to Ground
Neutral

BASIC WIRING TECHNIQUES
UNIT I

ASSIGNMENT SHEET #1--IDENTIFY TERMINALS ON 120-VOLT DEVICES

NAME ______________________________ SCORE ______________

Receptacle jacks and plug connector pins are not always identified on the outside of assembled devices. If an improperly wired device is suspected, a competent electrician or technician should know which pin or jack is supposed to be wired to which circuit.

Study Transparency #1 and associate memory aids with the devices to help you recall which jack is which. Examples of memory aids are, "It is big to be neutral," which implies that the large slot on the receptacle is neutral. Another example is, "Dynamite comes in small pakages," which implies that the small slot on the receptacle is the hot connector. Also, receptacles may be found wired sideways, on the ceiling, or in various positions, so do not merely memorize the positions shown on Transparency #1.

When you are certain you can identify the connectors of a receptacle or plug, put away your reference material. Write the proper terms, *neutral, hot,* or *ground* in the spaces provided on the following illustrations (Figures 17 and 18). Give your completed sheet to your instructor for evaluation.

FIGURE 17

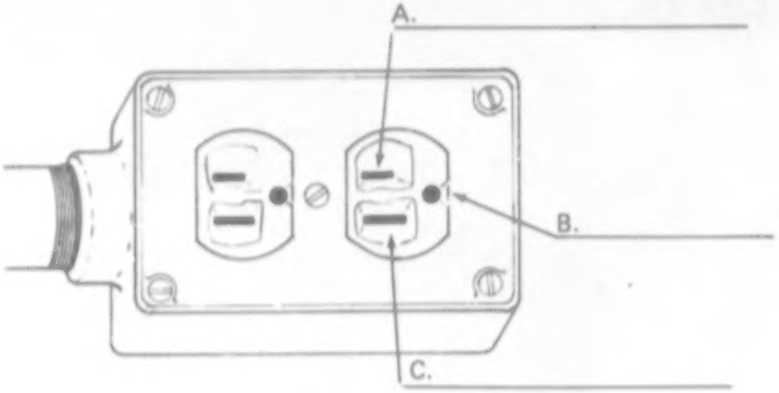
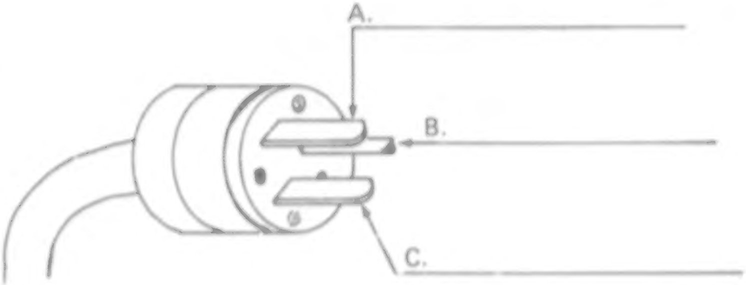


FIGURE 18



BASIC WIRING TECHNIQUES
UNIT I

ASSIGNMENT SHEET #2--DIAGRAM A DISTRIBUTION CIRCUIT

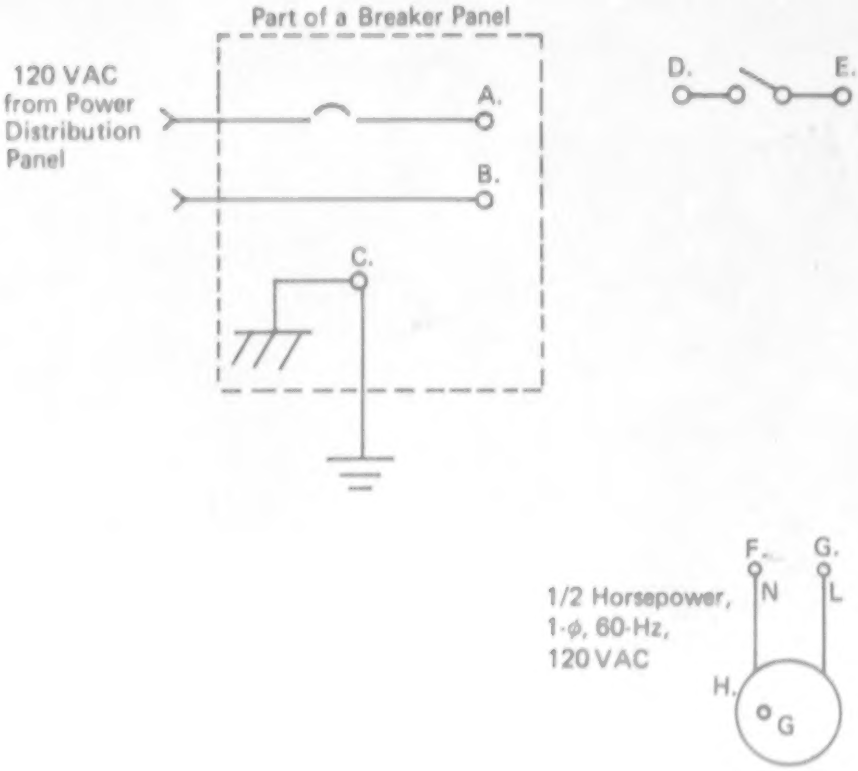
NAME______________________________________ SCORE ________________

Electricians and technicians often find it necessary to diagram a circuit before constructing it. A diagram can be used to analyze the circuit to ensure proper operation, to make certain electrical codes are followed, to keep as a troubleshooting aid in case of circuit failure, to determine materials required, or to refer to when planning additions or modifications to the plant or factory.

Before attempting to diagram the following circuit (Figure 19), review the circuit symbols given in Objective III of this unit and study the chart in Objective X (Transparency #3).

Use a pencil to draw interconnections between the components of the following illustration. Connect between the dots only. Write the color of each wire next to it. The motor should operate only when the switch is turned on.

FIGURE 19


Part of a Breaker Panel
120 VAC from Power Distribution Panel
A.
B.
C.
D.
E.
F.
G.
N
L
H.
G
1/2 Horsepower, 1-ϕ, 60-Hz, 120 VAC

BASIC WIRING TECHNIQUES
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. Hot

B. Ground

C. Neutral

D. Neutral

E. Ground

F. Hot

Assignment Sheet #2

A. A connects to D

B. B connects to F

C. E connects to G

D. C connects to H (safety ground)

BASIC WIRING TECHNIQUES
UNIT I

JOB SHEET #1--WIRE A PLUG TO A POWER CABLE

I. Equipment and materials

- A. Electrician's knife
- B. Flat blade screwdriver
- C. Rubber covered power cable--3 conductor, AWG #14, #16, or #18
- D. 120-volt plug with ground--10 to 20 amps
- E. Diagonal cutting pliers
- F. Wire stripping pliers
- G. *National Electrical Code*

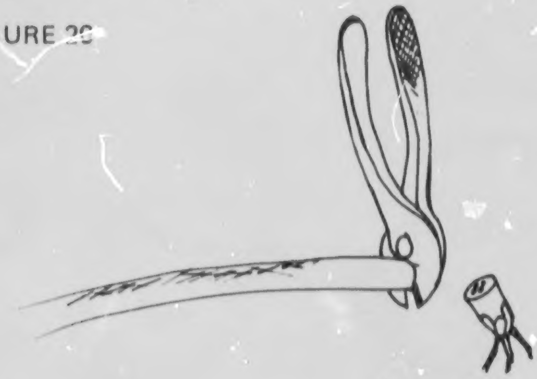
II. Procedure

A. Read sections A and B of Article 400 in the *National Electrical Code*

(NOTE: Ask your instructor about anything you do not understand.)

B. Use the diagonal cutting pliers to cut the end of the power cable if it is not already square (Figure 20)

FIGURE 20



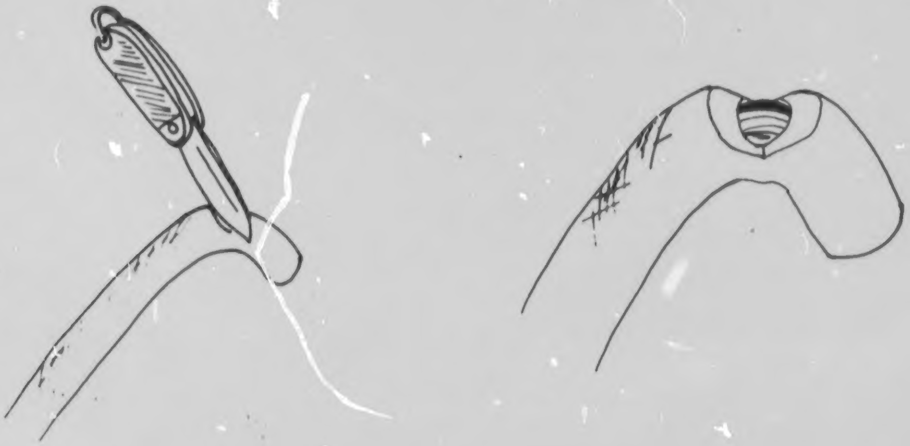
C. Bend the cable at a distance from the end approximately equal to the length of the body of the plug, not considering the pins

JOB SHEET #1

D. Slice the cable carefully at the peak of the arch where the rubber covering is stretched (Figure 21)

(NOTE: The outer cable covering will separate before the blade penetrates the wires.)

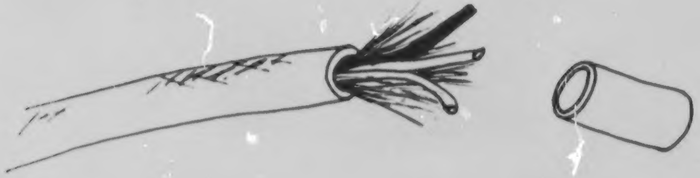
FIGURE 21



E. Rotate cable; bend and slice again until the covering is completely severed

F. Twist and pull the piece of covering from the end of the cable (Figure 22)

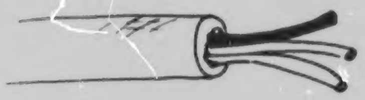
FIGURE 22



JOB SHEET #1

G. Separate the three conductors from any twine, rope, paper, or string, and cut this material off at the point where the outer covering was severed, leaving only the three conductors protruding from the cable (Figure 23)

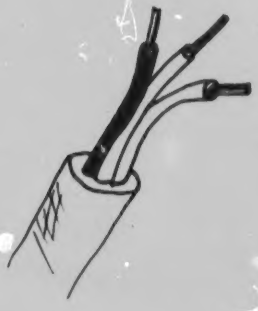
FIGURE 23



H. Use wire-stripping pliers to remove the insulation from the three conductors (Figure 24)

(NOTE: Match the stripping hole to the size of the wires. The wire size is printed on the outside cover of the cable and next to each slot on the stripping pliers. Cut away about ½ inch [1¼ cm] of insulation. If more than 10% of the small inside wire strands are cut, you will have to begin again at step A.)

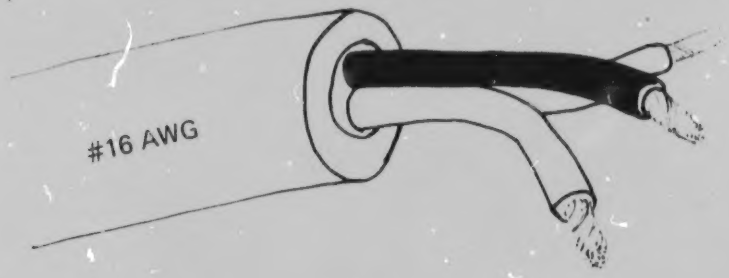
FIGURE 24



JOB SHEET #1

I. Twist the exposed strands together (Figure 25)

FIGURE 25



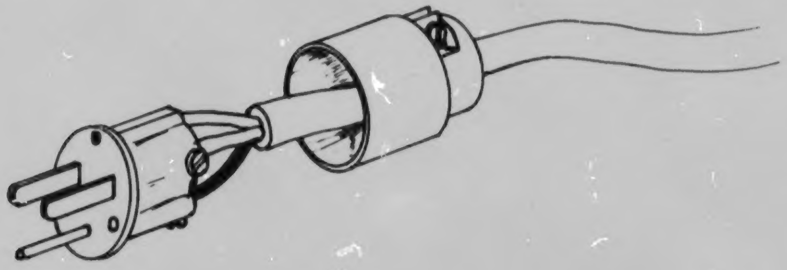
(NOTE: Show your work to the instructor.)

J. Disassemble the plug

K. Insert the cable into the plug

L. Bend the conductor clockwise around the proper screws, or insert them into the correct holes depending upon the type of plug you are working with (Figure 26)

FIGURE 26



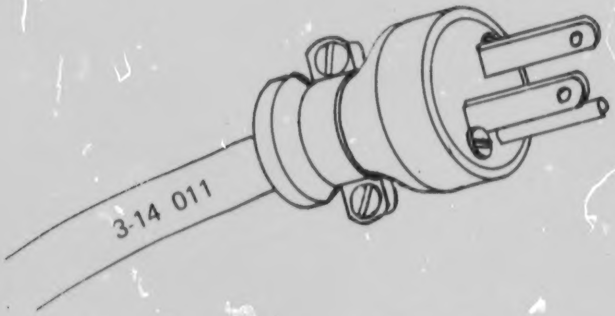
M. Tighten the screws that fasten the conductors

(NOTE: Check to see that no frayed strands of wire are out or hanging loose. Also recheck to see that the proper wire colors connect to the proper screws.)

JOB SHEET #1

N. Assemble plug and tighten any clamps which secure the cable (Figure 27)

FIGURE 27



O. Use an ohmmeter to check from the exposed end of the cable to the plug pins

(NOTE: Green wire should connect to the ground pin, white wire to the neutral pin, and black wire to the power pin. No two wires should connect to each other. Show your work to the instructor. Ask the instructor if you should disassemble the plug.)

P. Put tools and materials away

BASIC WIRING TECHNIQUES
UNIT I

JOB SHEET #2--CHECK A 120-VOLT RECEPTACLE FOR PROPER WIRING

I. Equipment and materials

- A. Multimeter
- B. *National Electrical Code*
- C. Access to a live 120-volt AC, receptacle having a safety ground

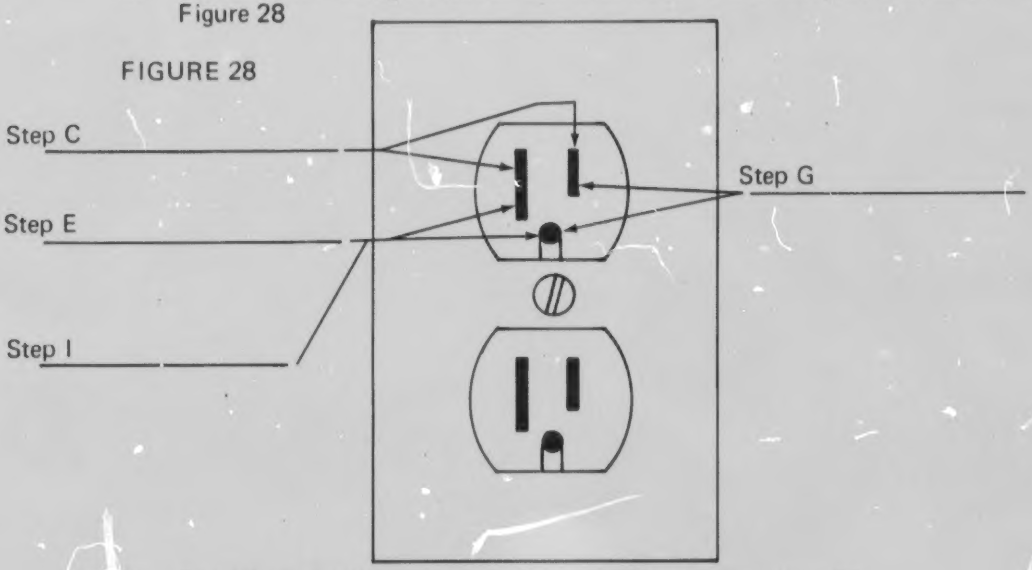
II. Procedure

- A. Read sections 410-56, 410-57, 410-58, and 250-21 of the *National Electrical Code*

  (NOTE: Ask your instructor about anything you do not understand.)

- B. Set the voltmeter controls to measure in the range of 120 volts AC
- C. Measure the voltage between the two slots of the receptacle as shown in Figure 28

FIGURE 28



- D. Record your measurement in the space provided in Figure 28

  (NOTE: If the voltage is not between 105 and 130 volts, it is abnormal. Have your instructor check it or explain why it is not normal. There are special testers that merely plug into the receptacle to automatically check voltages and ground connections. OSHA inspectors often use these types for in-plant inspections to ensure the safety of workers. These testers are faster and easier than the method presented here.)

JOB SHEET #2

E. Measure voltage between the long slot and the ground jack

(NOTE: This measurement should be zero volts because the long slot is supposed to be the neutral jack. If you measure near 120 volts, this indicates that the receptacle or the circuit supplying it is miswired. Notify your instructor if this is the case. If you measure near zero volts, select lower ranges on the AC voltmeter scale until a voltage can be detected or until the millivolt range is selected.)

F. Record this voltage in the space provided in Figure 28

G. Measure the voltage between the short slot and the ground jack

(NOTE: This should be near 120 volts and identical to that measured in step C.)

H. Record your reading in the space provided in Figure 28

(NOTE: If the measurement between the long slot [neutral] and the ground jack was at or near zero, proceed with steps I and J.)

I. Set the meter for DC voltage measurement and begin at a high DC scale near 100 volts; select lower ranges until the millivolt range is selected or until a voltage is detected

J. Record this voltage in the space provided in Figure 28

(NOTE: DC voltages exist between two ground points as a result of electrochemical action or high current DC machinery operating on the circuit. Significant DC voltage levels are unacceptable and suggest defective connections or improper wiring practices. Review Article 250-21 of the *National Electrical Code*, and ask your instructor to explain any significant DC voltage you may have measured.)

K. Give your measurement sheet to your instructor for evaluation

L. Put equipment and materials away

BASIC WIRING TECHNIQUES
UNIT I

JOB SHEET #3--CRIMP TERMINAL CONNECTORS ONTO CONDUCTORS

I. Equipment and materials

A. Electrical wire--Insulated, stranded, from AWG #20-#14

B. Terminal connectors--Crimp type, sized for wire used

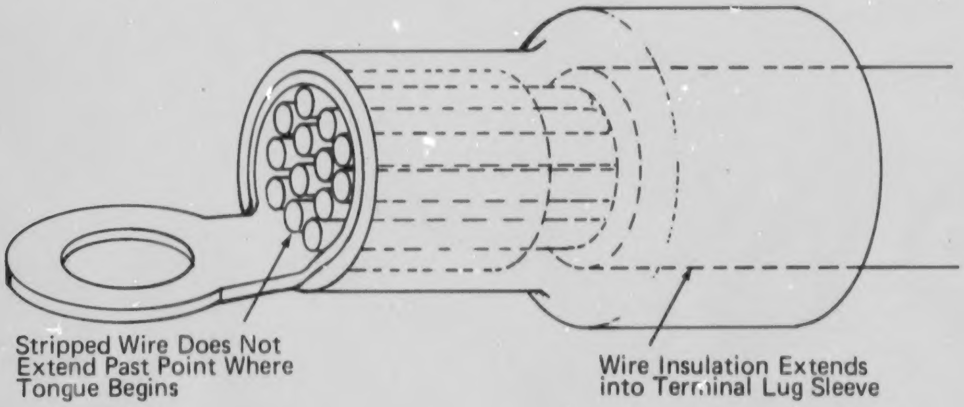
C. Crimping pliers

II. Procedure

A. Judge the amount of insulation that must be stripped from the wire so that the stripped end will fit into the terminal up to the point where the tongue begins (Figure 29)

(NOTE: Insulation must not be removed so far that it will not fit into the enlarged end of the terminal insulating sleeve.)

FIGURE 29


Stripped Wire Does Not Extend Past Point Where Tongue Begins
Wire Insulation Extends into Terminal Lug Sleeve

B. Note the wire size, and find the appropriate slot in the jaws of the wire strippers

(NOTE: Wise is usally marked as "AWG #14," for example, and the stripping jaws are usually marked. If you cannot determine the size of the wire, ask your instructor.)

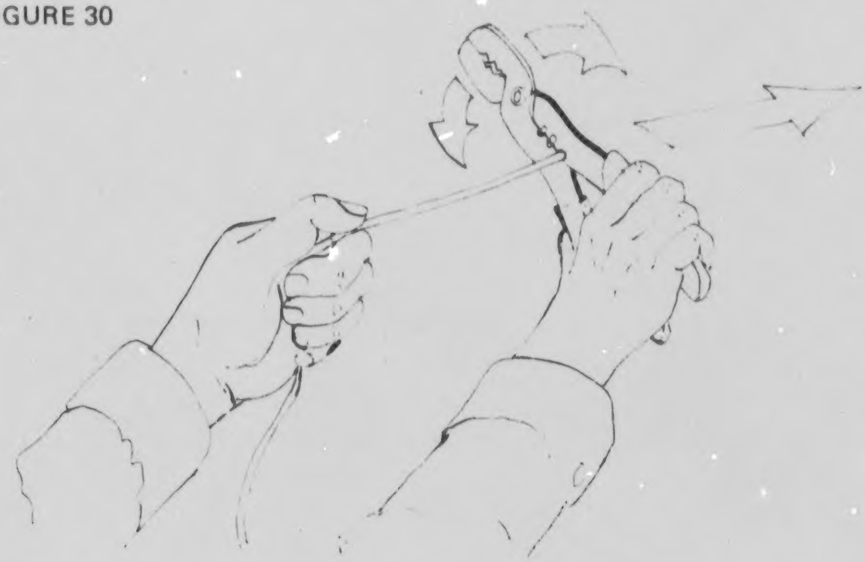
C. Place wire into the stripping slot at the point where insulation is to be removed

D. Grip down firmly on the handles of the pliers

JOB SHEET #3

E. Twist the pliers about the wire to cut the insulation completely; then push away until the piece is severed from the wire end (Figure 30)

FIGURE 30

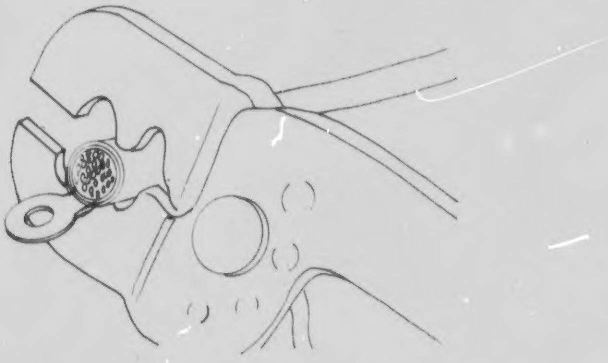


F. Place terminal lug onto the end of the wire

G. Insert the assembled wire and lug into the crimping jaws of the pliers (Figure 31)

(NOTE: Pliers may have several jaws for several sized lugs. Ask your instructor which you should use for the lug you have. Both the lug and the crimping jaws may be marked, indicating a particular size, such as 16-14.)

FIGURE 31

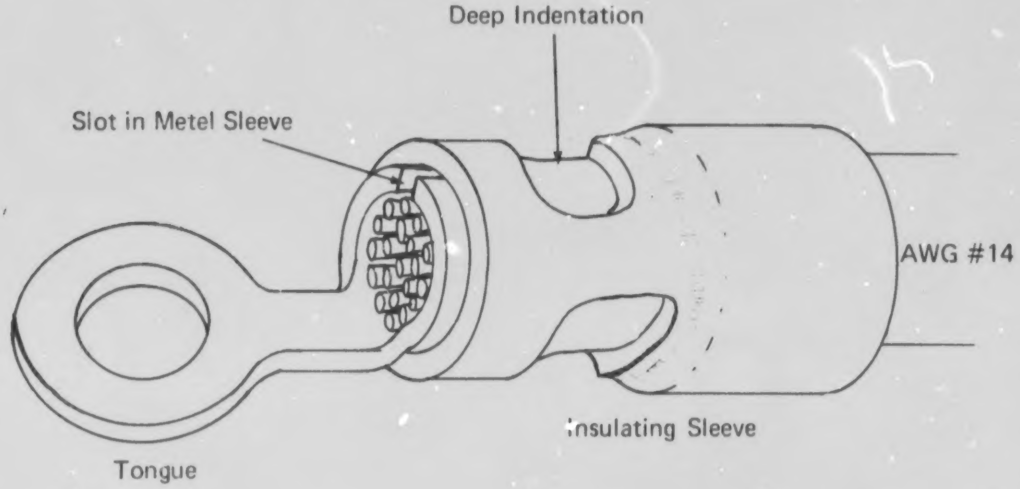


JOB SHEET #3

H. Crimp the lug so that a deep indentation is made on the side of the lug away from the tongue (Figure 32)

(NOTE: This should be where the metal lug sleeve has a slot running down its length. The crimp should be centered on the undersized part of the lug sleeve, at the center inside of the metal sleeve.)

FIGURE 32



I. Pull on the lug to make certain that it is well-secured to the wire

(NOTE: This should always be done after a crimp connection is made. If the lug pulls loose, you probably used crimping jaws that were too large. If the insulating sleeve is damaged severely, you probably used crimping jaws that were too small.)

J. Cut the wire about four inches (10 cm) back from the lug

K. Repeat the above procedures until the several lugs given to you by the instructor have been crimped

(NOTE: Show your crimp connections to the instructor.)

L. Put equipment and materials away

BASIC WIRING TECHNIQUES
UNIT I

JOB SHEET #4--WIRE A PLUG TO A THREE-PHASE POWER CORD

I. Equipment and materials

A. Electrician's knife

B. Flat blade screwdriver

C. Four conductor power cable--Size AWG #18, #16, or #14

D. Plug--3-ϕ, 4-conductor, 250-volt, 20-amp

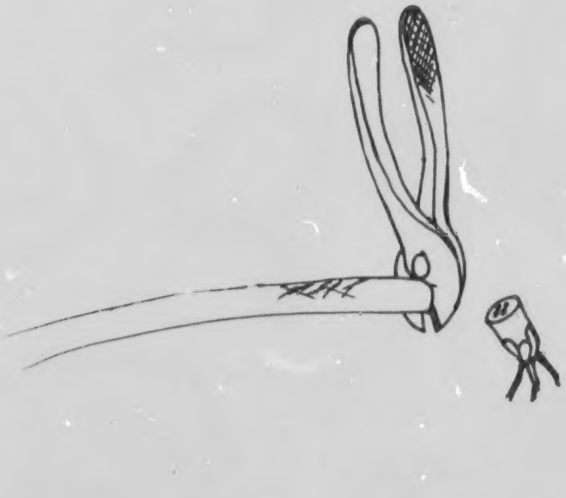
E. Diagonal pliers

F. Cutting-crimping tool

II. Procedure

A. Use the diagonal cutting pliers to cut the end of the power cable square (Figure 33)

FIGURE 33



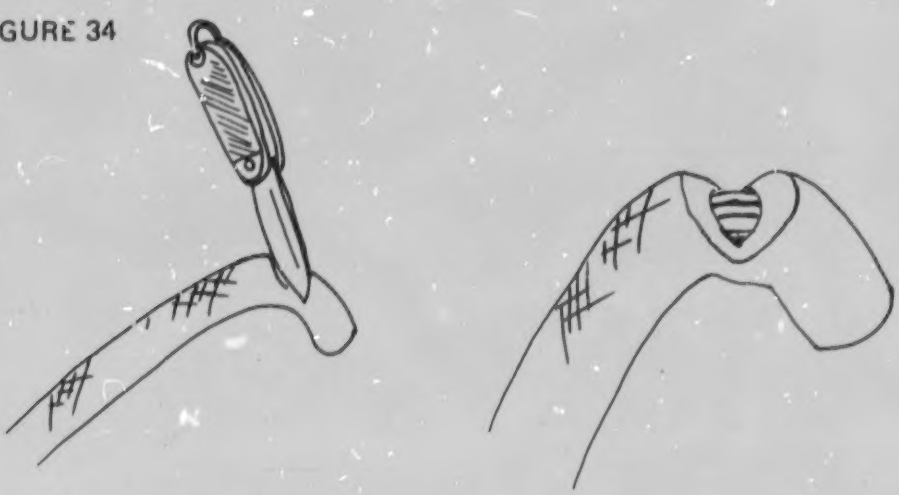
B. Bend the cable at a distance from the end approximately equal to the length of the body of the plug, not considering the pins

JOB SHEET #4

C. Slice the cable carefully at the peak of the arch where the rubber covering is stretched (Figure 34)

(NOTE: The outer cable covering will separate before the blade penetrates the wires.)

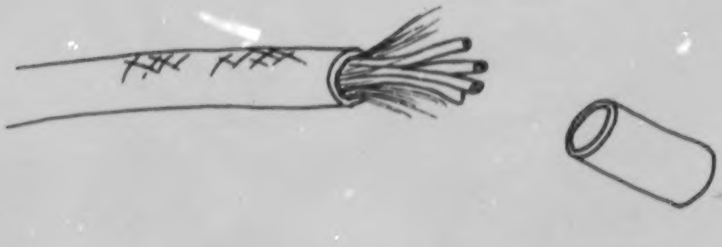
FIGURE 34



D. Rotate cable; bend and slice again until the covering is completely severed

E. Twist and pull the piece of covering from the end of the cable (Figure 35)

FIGURE 35

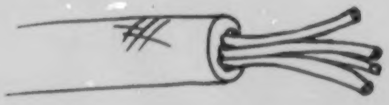


F. Separate the four conductors from any twine, rope, paper, or string

JOB SHEET #4

G. Cut this material off at the point where the outer covering was severed, leaving only the four conductors protruding from the cable (Figure 36)

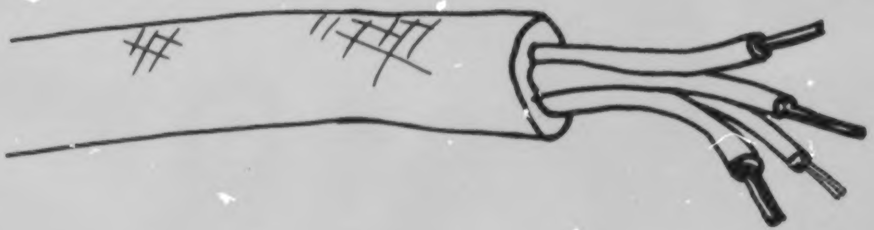
FIGURE 36



H. Use the cutting-crimping tool to remove the insulation from the conductors (Figure 37)

(NOTE: Match the stripping hole to the size of the wires. The wire size is printed on the outside cover of the cable and next to each slot on the cutting tool. Cut away about 1/2 inch [1 1/4 cm] of insulation. If more than 10% of the small inside wire strands are cut, you will have to begin again at Step A.)

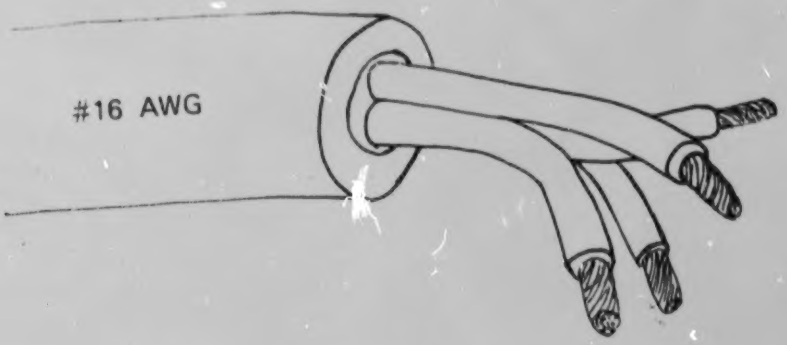
FIGURE 37



JOB SHEET #4

I. Twist the exposed strands together (Figure 38)

FIGURE 38



(NOTE: Show your work to the instructor.)

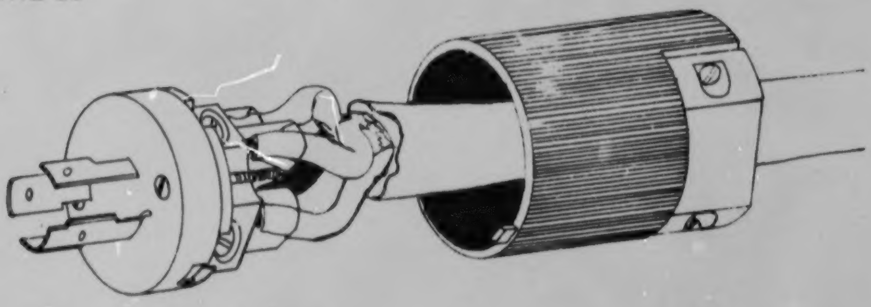
J. Disassemble the plug

K. Insert the cable into the plug

L. Insert the wires into the correct holes in the plug, depending upon which type power input is available (Figure 39)

EXAMPLES: Three-phase "Y," three-phase delta with neutral, and three-phase delta with ground

FIGURE 39



M. Tighten the screws that fasten the conductors

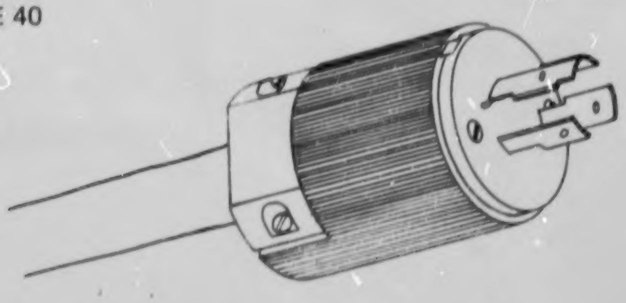
(NOTE: Check to see that no frayed strands of wire are out from under the connector. Recheck to see that the proper wire colors are connected to the proper connections.)

JOB SHEET #4

N. Assemble plug (Figure 40)

(NOTE: Tighten any clamps which secure the cable; check to see that plug housing clamps down on the insulation and not on the conductors themselves.)

FIGURE 40



O. Use an ohmmeter to check the pins of the plug, being sure that no two connections are shorted together

(NOTE: Show your work to instructor. Ask instructor if you should disassemble the plug.)

P. Put equipment and materials away

BASIC WIRING TECHNIQUES
UNIT I

TEST

NAME______________________________ SCORE ______________

1. Match terms associated with basic wiring techniques to their correct definitions. Write the correct numbers in the blanks. Definitions are continued on the next page.

_____a. Alternating current circuit with only two points of entry; points are in phase

_____b. Electrical power generated such that the three armature windings have output voltages 120° out of phase with each other

_____c. Situation where electrical current takes an improper path; usually due to faults in insulation, contact between terminals of different voltages, or wiring errors

_____d. Electromagnetic device that opens a circuit automatically when the current exceeds a predetermined value

_____e. Electrical switch controlled by an electromagnet

_____f. Electromagnetic mechanism used from remote locations to open valves or to control mechanical latches

_____g. Magnet that results from electricity passing through a coil of wire

_____h. Square root of the time average of the square of a quantity; value of AC voltage, current, or power which compares to the equivalent DC value for effectiveness; value of AC normally specified or understood; value of AC normally measured with meters

_____i. Connection or conductor terminated at a metal case or electrical equipment frame, which may or may not be connected to earth ground

_____j. Connection or conductor terminated within the soil, usually through grounding rods driven into or buried in the ground near electrical equipment

1. Solenoid
2. Circuit breaker
3. Single phase
4. Root-mean-square
5. Short circuit
6. Electromagnet
7. Polyphase
8. Relay
9. Earth ground
10. Neutral conductor
11. Chassis ground
12. Hot conductor
13. Ground conductor

TEST

______k. Connects to power source; operates at the rated voltage; carries current

______l. Connects electrical equipment directly to earth ground, but does not normally carry any current; operates at zero volts and carries current only if faults or short circuits occur

______m. Connects to earth ground, usually at transformer supplying power to building or circuit; operates at zero volts, but carries current between source of power and equipment being operated

2. Match symbols and abbreviations associated with basic wiring techniques to their correct interpretations. Write the correct numbers in the blanks.

______a. Terminal board

______b. American Wire Gauge

______c. Root-mean-square

______d. Fuse

______e. Ground

______f. Line

______g. Neutral

______h. Aluminum

______i. Copper

______j. With ground wire

______k. Phase

______l. Hertz

______m. National Electrical Manufacturers Association

______n. Occupational Safety and Health Administration

______o. Underwriters Laboratories

______p. Alternating current

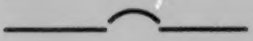
______q. Direct current

1. **G**
2. **TB**
3. **F**
4. **L**
5. **rms**
6. **AWG**
7. **Cu**
8. **ϕ**
9. **N**
10. **NEMA**
11. **w/g**
12. **UL**
13. **OSHA**
14. **Al**
15. **Hz**
16. **DC**
17. **AC**

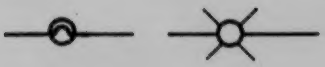
TEST

3. Identify circuit symbols associated with basic wiring. Write the correct names in the blanks below each symbol.

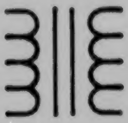
Earth ground	Chassis ground
Fuse	Switch
Transformer	Lamp
Connecting wires	Wires crossing but not connecting
Single-phase AC motor	Circuit breaker



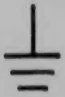
a. ______________________



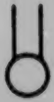
b ______________________



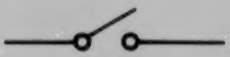
c. ______________________



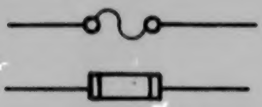
d. ______________________



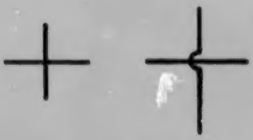
e. ______________________



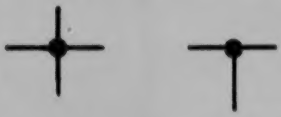
f. ______________________



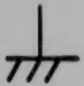
g. ______________________



h. ______________________



i. ______________________



j. ______________________

TEST

4. State power characteristics of an ordinary wall receptacle.

   a. Voltage-- ____________________

   b. Phase-- ____________________

   c. Frequency-- ____________________

   d. Connection-- ____________________

5. List industrial applications for a 120-volt, alternating current, single-phase, 60-hertz, 2-wire, with ground power source.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

   e. ____________________

   f. ____________________

   g. ____________________

   h. ____________________

6. Distinguish between advantages and disadvantages of a 120-volt, alternating current, single-phase, 60-hertz, 2-wire, with ground power source. Write an "A" for advantage and a "D" for disadvantage.

   _____a. Equipment sizes are excessive for power applications

   _____b. Power delivered--compared to the number and size of the wires--is not as efficient as with polyphase techniques

   _____c. Sixty hertz in not as efficient for motors and transformers as higher frequencies, such as 400 hertz

   _____d. Most small tools and appliances are designed to operate at this power

   _____e. Large currents required to furnish equivalent power can result in excessive line loss, voltage drop, and inefficiency

   _____f. Common to homes, offices, schools, commercial buildings, and industrial plants

   _____g. Most ordinary wires, switches, and electrical components are capable of operating safely at this power

   _____h. Large size of equipment can cost more than smaller, higher voltage equipment of the same power capability

TEST

______i. Standard connectors, cables, and receptacles are economical and widely available

______j. Voltage is sufficient for lengthy control wiring with numerous switches, solenoids, and relays

______k. Alternating current equipment, lighting apparatus, and cables can cause interference in sensitive test equipment and control systems

______l. Industrial power distribution systems may not have 120-volt alternating current available unless extra transformers are installed

______m. Reversing direction of rotation for single-phase, alternating current motors is more complex than for direct current or polyphase motors

______n. Speed control of alternating current motors is more difficult than with direct current

______o. Voltage does not pose an unacceptable hazard in most applications, even though it can be deadly

7. Describe two configurations of three-phase or polyphase power.

a. ______________________________

____

b. ______________________________

____

8. Name advantages of three-phase or polyphase power.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

TEST

9. Match agencies and organizations that control electrical wiring practices to their correct activities. Write the correct numbers in the blanks.

_____a. Sets standards for electrical equipment compatability

_____b. Publishes the *National Electrical Code*, a handbook of nationally accepted rules and procedures for electrical wiring

_____c. Tests electrical equipment and apparatus for safety and dependability

_____d. Inspects plants and electrical equipment to ensure employee safety

1. National Fire Protection Association
2. Underwriters Laboratories
3. Occupational Safety and Health Administration
4. National Electrical Manufacturers Association

10. Complete a chart of characteristics of a 120-volt, alternating current, single-phase, 60-hertz circuit. (See next page.)

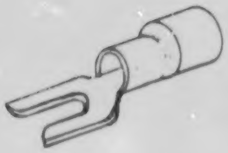
TEST

CHARACTERISTIC	CONDUCTOR		
	HOT WIRE	**NEUTRAL WIRE**	**SAFETY GROUND**
COLOR CODE OF WIRE	a. ____________	WHITE OR NATURAL GREY AS REQUIRED BY THE *NATIONAL ELECTRICAL CODE*	GREEN, GREEN WITH YELLOW OR A WHITE STRIPE, OR BARE METAL AS REQUIRED BY THE *NATIONAL ELECTRICAL CODE*
CONDUCTION OF CURRENT	NORMALLY CARRIES CURRENT	NORMALLY CARRIES CURRENT	b. ____________
OPERATING VOLTAGE	120 VOLTS AC AT 60 HERTZ	c. ____________	ZERO VOLTS
SWITCHES OR FUSES ALLOWED	SWITCHES AND FUSES ORDINARILY INTERRUPT THE CONTINUITY OF THIS CIRCUIT	d. ____________	SWITCHES, FUSES, AND CIRCUIT INTERRUPTIONS ARE NOT ALLOWED
COLOR OF CONNECTING SCREW ON RECEPTACLES AND PLUGS	e. ____________	CHROME OR SILVER COLORED	GREEN
LETTER DESIGNATOR	f. ____________	g. ____________	h. ____________

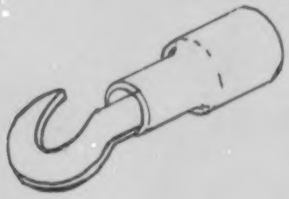
TEST

11. Identify common crimp-type terminal connectors. Write the correct name in the blank below each connection.

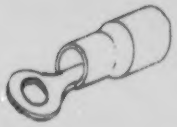
Ring tongue
Spade tongue
Quick disconnect
Hook tongue
Flanged-tip spade tongue
Block ring tongue



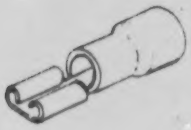
a. ______________________



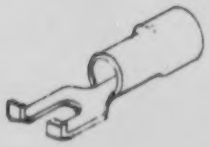
b. ______________________



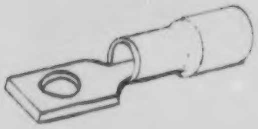
c. ______________________



d. ______________________



e. ______________________



f. ______________________

TEST

(NOTE: Test questions 12-14 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

12. Identify terminals on 120-volt devices.

13. Diagram a distribution circuit.

14. Demonstrate the ability to

    a. Wire a plug to a power cable.

    b. Check a 120-volt receptacle for proper wiring.

    c. Crimp terminal connectors onto conductors.

    d. Wire a plug to a three-phase power cord.

BASIC WIRING TECHNIQUES
UNIT I

ANSWERS TO TEST

1. a. 3
   b. 7
   c. 5
   d. 2
   e. 8
   f. 1
   g. 6
   h. 4
   i. 11
   j. 9
   k. 12
   l. 13
   m. 10

2. a. 2
   b. 6
   c. 5
   d. 3
   e. 1
   f. 4
   g. 9
   h. 14
   i. 7
   j. 11
   k. 8
   l. 15
   m. 10
   n. 13
   o. 12
   p. 17
   q. 16

3. a. Circuit breaker
   b. Lamp
   c. Transformer
   d. Earth ground
   e. Single-phase AC motor
   f. Switch
   g. Fuse
   h. Wires crossing but not connecting
   i. Connecting wires
   j. Chassis ground

ANSWERS TO TEST

4. a. 120 volts, rms
   b. Single
   c. 60 hertz
   d. Two wire with safety ground

5. a. Small hand and shop tools
   b. Wall clocks and time clocks
   c. Lamps and light fixtures
   d. Office equipment
   e. Electronic test equipment
   f. Laboratory equipment
   g. Control wiring for systems
   h. Small motors, fans, and pumps

6. a. D
   b. D
   c. D
   d. A
   e. D
   f. A
   g. A
   h. D
   i. A
   j. A
   k. D
   l. D
   m. D
   n. D
   o. A

7. Description should include
   a. Wye--Coils joined at one end; "Y" shaped
   b. Delta--Coils hooked in series; triangular

8. a. Smaller machines than those used for single-phase
   b. Simpler construction than that needed for single-phase
   c. Better operating characteristics than single-phase

ANSWERS TO TEST

d. More efficient power distribution than that in single-phase

e. Self-starting in AC induction motors

f. AC ripple easier to filter in DC power supplies

g. Two different voltages available

9. a. 4

b. 1

c. 2

d. 3

10. a. Almost any color except white or natural grey, usually black or red

b. Only carries current when short circuits or faults exist

c. Zero volts

d. Normally switches and fuses are not allowed

e. Brass or copper colored

f. L

g. N

h. G

11. a. Spade tongue

b. Hook tongue

c. Ring tongue

d. Quick disconnect

e. Flanged-tip spade tongue

f. Block ring tongue

12. Evaluated to satisfaction of instructor

13. Evaluated to satisfaction of instructor

14. Performance skills evaluated to satisfaction of instructor

SOLDERING TECHNIQUES
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to distinguish between good and bad soldering joints, solder an electronic component to a printed circuit board, solder a terminal lug to a wire, and solder a heat-sensitive component to a printed circuit board. This knowledge will be shown by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with soldering techniques to their correct definitions.
2. Match symbols associated with soldering techniques to their correct definitions.
3. State primary purposes for solder in electrical applications.
4. Match general soldering tool sizes to their correct applications.
5. Identify soldering tools and materials.
6. Classify metals according to their ability to be soldered.
7. Name the solder type used for most electrical applications.
8. Label common wire splices.
9. Distinguish between correct and incorrect soldering practices.
10. Distinguish between good and bad characteristics of solder joints.
11. Match chemical interpretations to their correct descriptions.
12. Select correct soldering tool sizes.
13. Select metals according to their ability to soldered.
14. Demonstrate the ability to
    a. Prepare a soldering iron tip for use.
    b. Solder seven types of wire splices.
    c. Solder an electronic component to a printed circuit board.
    d. Solder a terminal lug to a wire.
    e. Solder a heat-sensitive component to a printed circuit board.

SOLDERING TECHNIQUES
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   (NOTE: Students should be given or have access to the latest edition of the *National Electrical Code*.)

   G. Make an assortment of good and bad soldering joints for display.

   (NOTE: Make poor joints by burning wires under a flame until carboned, then soldering without flux. Make a cold solder joint by moving wires while solder is setting.)

   H. Demonstrate the common wire splices.

   I. Demonstrate the use of cleaners, fluxes, wire braid, and desoldering suction bulbs.

   J. After Job Sheet #2 is completed, select and show to class the best soldered splice in each of the seven types

   K. Display on a board students' best splices completed in Job Sheet #2. Label each splice type and identify who spliced it.

   L. Repeat Job Sheets #2 and #3 several times.

   M. Give test.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency masters

      1. TM #1--Printed Circuit Board and Components

      2. TM #2--Soldering Tools

SUGGESTED ACTIVITIES

3. TM #3--Soldering Tools (Continued)

4. TM #4--Soldering Tools (Continued)

5. TM #5--Solid Wire Splices

6. TM #6--Stranded Wire Splices

7. TM #7--Other Wire Splices

E. Assignment sheets

1. Assignment Sheet #1--Select Correct Soldering Tool Sizes

2. Assignment Sheet #2--Select Metals According to their Ability to be Soldered

F. Answers to assignment sheets

G. Job Sheets

1. Job Sheet #1--Prepare a Soldering Iron Tip for Use

2. Job Sheet #2--Solder Seven Types of Wire Splices

3. Job Sheet #3--Solder an Electronic Component to a Printed Circuit Board

4. Job Sheet #4--Solder a Terminal Lug to a Wire

5. Job Sheet #5--Solder a Heat-Sensitive Component to a Printed Circuit Board

H. Test

I. Answers to test

III. Unit references

A. "Common Production Soldering Problems." *Circuits Manufacturing.* Westburg, New York: Multicore Solders, July 1977.

B. *Introduction to Electricity and Electronics.* 3rd ed. "Conductors," Lesson Eight. Barington, Illinois: TPC Training Systems.

C. *Kester Solder.* No. OEM-110. Chicago, Illinois: Kester Solder, 1977.

D. *National Electrical Code.* Boston: National Fire Protection Association, 1980.

E. Zbar, Paul B., and Joseph G. Sloop. *Electricity-Electronics Fundamentals.* 2nd ed. New York: McGraw-Hill, 1977.

SOLDERING TECHNIQUES
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Solder--Soft metal alloy of tin and lead used for plating or fusing metals together

(NOTE: Solder is available in many forms, including solid wire, wire with paste, flux, bars, and washers. Sometimes solder includes other metals, such as silver, gold, or cadmium.)

B. Flux--Solution that cleans metals before or during soldering, or chemically acts to aid the fusion process

(NOTE: There are many types of fluxes for different types of soldering and welding. Fluxes perform different jobs for various purposes and applications. Do not use unspecified fluxes on any application.)

C. Rosin--Type of flux used in electrical and electronic soldering applications; filled-in core of solder ("rosin-core solder"), which dispenses as the solder melts; non-corrosive and non-conductive

D. Printed circuit board--1/16-inch plastic, fiberglass, or phenolic board upon which copper strips interconnect between mounted components (Transparency #1)

E. Run--Strip of conductor on a printed circuit board (Transparency #1)

F. Pad--Round terminal connection point on a printed circuit board where component lead wires are attached (Transparency #1)

G. Solder joint--Junction of two or more metals fused with solder

H. Integrated circuit device--Solid-state electronic component comprised of many components miniaturized into a single, small package; usually characterized by having from eight to sixteen leads (Transparency #1)

I. Transistor--Solid-state device common to modern circuitry varying in size and function; usually characterized by three leads (Transparency #1)

J. Wicking--Flow of solder under the insulation of covered wire

K. Splice--To unite (connect) two wires to form a continuous length

INFORMATION SHEET

L. Fillet--Solder-welding two edges at right angles

EXAMPLES:

FIGURE 1

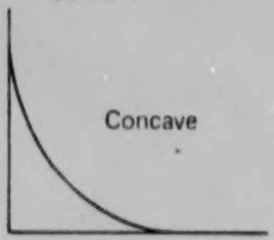
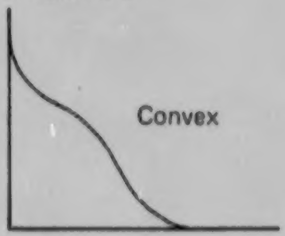


FIGURE 2



M. Convex--Having a curved form which bulges outward

N. Concave--Having a curved form which bulges inward

O. Galvanized--Surface on which zinc has been deposited by the process of hot dipping or electroplating

P. Phenolic board--Plastic material (thermosetting resin) which becomes permanently hardened when subjected to heat; originally known as Bakelite® ; used for printed circuit board construction

II. Symbols associated with soldering

(NOTE: Many of these symbols are found on conductors and materials; they indicate the metals involved. They are also used on connectors to indicate which types of conductors they will connect.)

A. **Sn**--Tin

B. **Pb**--Lead

C. **Ag**--Silver

D. **Al**--Aluminum

E. **Au**--Gold

F. **Cd**--Cadmium

G. **PC**--Printed circuit

H. **Cu**--Copper

I. **Ni**--Nickel

J. **W**--Watt

INFORMATION SHEET

III. Primary purposes for solder in electrical applications

A. Makes connections with virtually no resistance to electrical current flow

EXAMPLE: Components soldered to printed circuit boards

B. Prevents corrosion of conductors, connections, and parts

EXAMPLES: Printed circuit runs are often entirely covered with solder; terminal lugs are often coated with solder

C. Makes connections mechanically stronger

EXAMPLE: Soldered connections will not pull apart as easily as wires that are merely twisted together

D. Seals containers to keep out dust and moisture

EXAMPLES: Radio frequency crystal cannisters are sealed with solder; small, encased transformers or relays may be sealed with solder

IV. General soldering tool sizes and applications (Assignment Sheet #1)

(NOTE: Ratings for soldering tools for particular jobs are limited for general applications and can vary considerably. Nevertheless, these ratings serve as guidelines for students until judgment is gained through experience with various applications.)

A. 150 to 250 watts--For use with large connectors and circuits rated 30 to 50 amperes or greater

B. 40 to 150 watts--For use with vacuum tube circuits, connectors, and circuits rated 10 to 30 amperes

C. 20 to 40 watts--For use with transistor circuits involving components rated 1/2-watt or larger and their associated printed circuit boards, and circuits rated 1 to 10 amperes

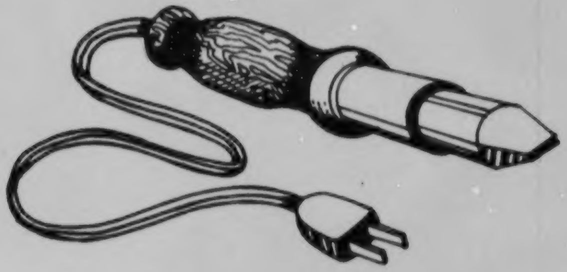
D. 20 watts or less--For use with circuits containing components rated less than 1/2-watt, integrated circuit devices, and circuits rated less than 1 ampere

INFORMATION SHEET

V. Soldering tools and materials (Transparencies #2-#4; Figures 3-12)

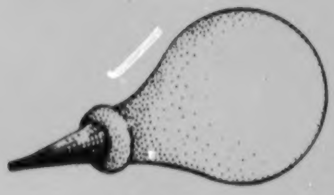
A. Large soldering iron

FIGURE 3



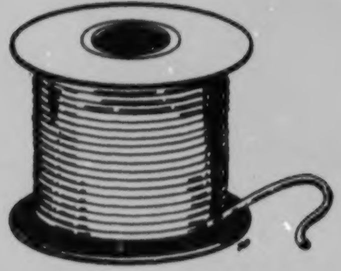
B. Desoldering suction bulb

FIGURE 4



C. Spool of solder wire

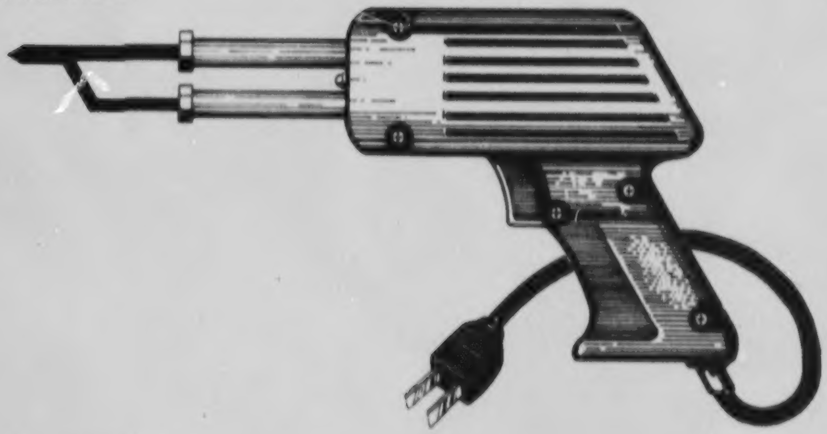
FIGURE 5



INFORMATION SHEET

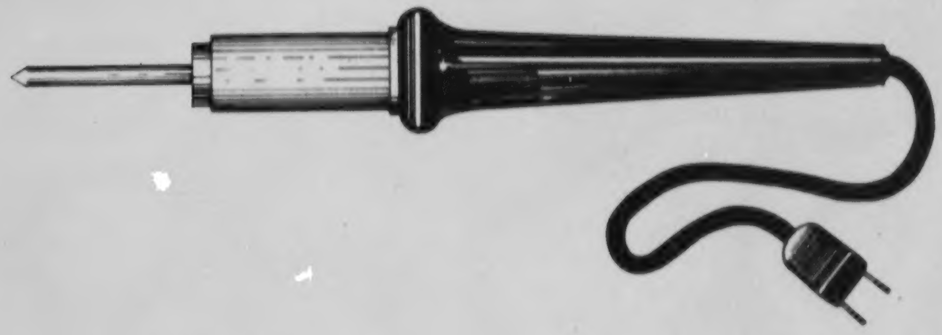
D. Soldering gun

FIGURE 6



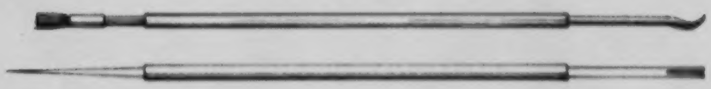
E. Pencil iron

FIGURE 7



F. Soldering aids

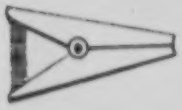
FIGURE 8



INFORMATION SHEET

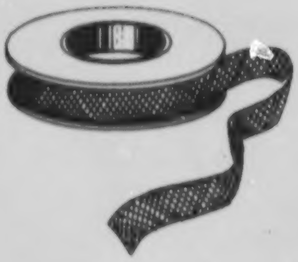
G. Heat sink

FIGURE 9



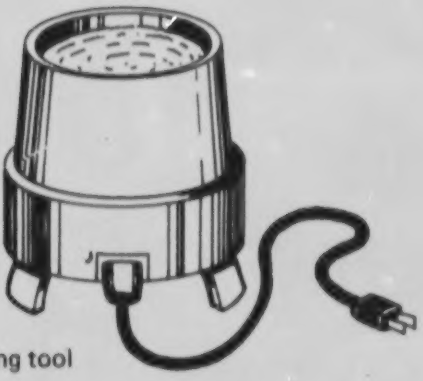
H. Solder wick (wire braid)

FIGURE 10



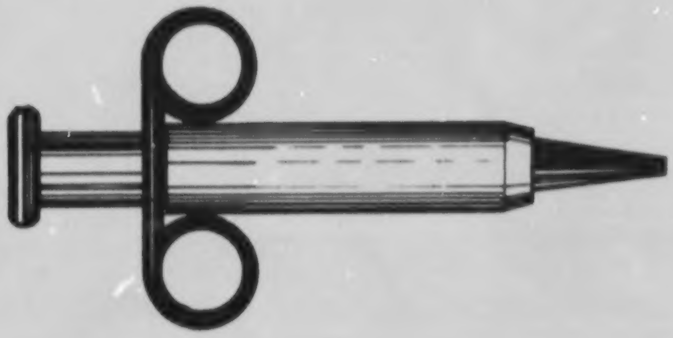
I. Solder pot

FIGURE 11



J. Spring-loaded desoldering tool

FIGURE 12



INFORMATION SHEET

VI. Ability of metals to be soldered (Assignment Sheet #2)

(NOTE: Different metals require different alloys of solder, as well as different fluxes, preparations, and temperatures.)

A. Metals that solder readily

1. Copper
2. Gold
3. Platinum
4. Tin
5. Silver
6. Cadmium plate

B. Metals that solder reasonably well

1. Lead
2. Nickel
3. Bronze
4. Brass

C. Metals that are difficult to solder

1. Galvanized
2. Mild steel
3. Nickel-tin alloy
4. Aluminum

D. Metals extremely difficult to solder

1. Chromium
2. Stainless steel

VII. Solder type used for most electrical applications--60% tin and 40% lead with rosin core

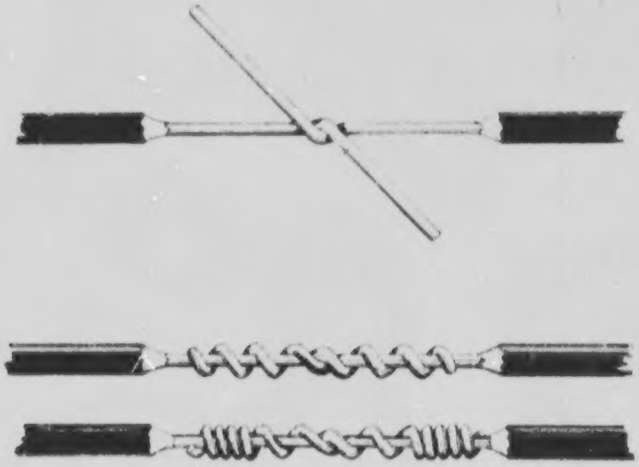
(NOTE: This solder is designated "60/40" and should not be confused with "40/60" which is another alloy commonly manufactured.)

INFORMATION SHEET

VIII. Common wire splices (Transparencies #5-#7; Figures 13-19)

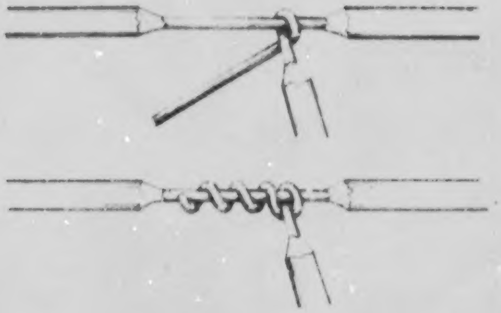
A. Simple splice for solid wire

FIGURE 13



B. Simple tap for solid wire

FIGURE 14

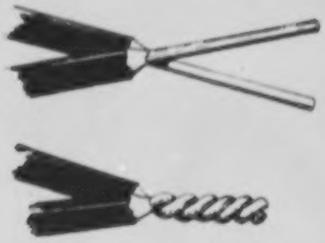


(NOTE: Simple tap is mechanically strong and does not break the continuity of the main wire.)

INFORMATION SHEET

C. Pigtail splice for solid wire

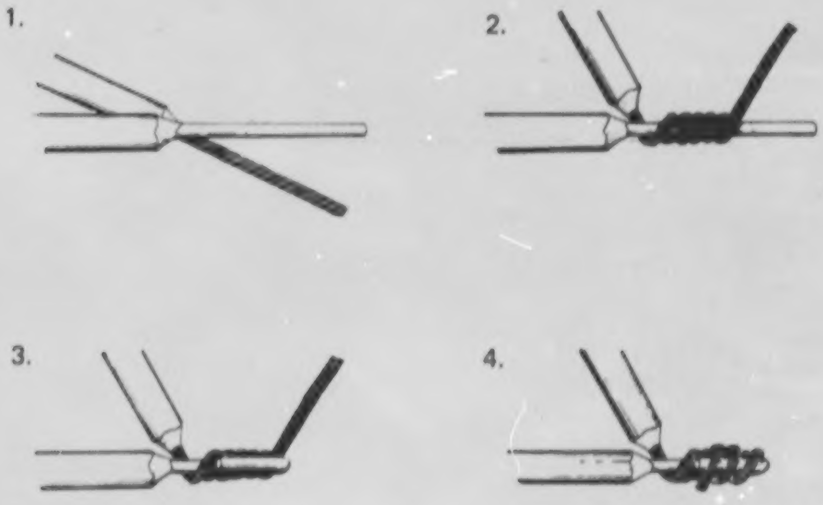
FIGURE 15



(NOTE: Pigtail splice is easily soldered in a solder pot and is easily taped in confined spaces.)

D. Fixture splice for solid wire and stranded wire connection

FIGURE 16

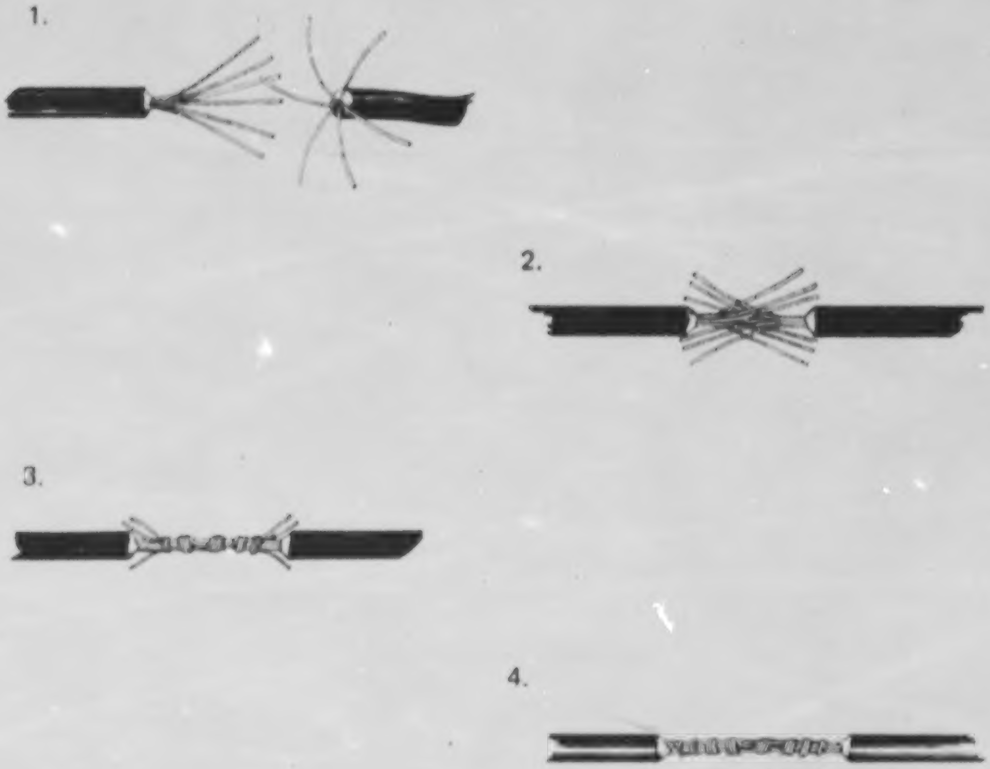


(NOTE: Fixture splice strongly secures stranded wire to solid wire, is easily soldered in a solder pot, and is easily taped in confined spaces.)

INFORMATION SHEET

E. Simple splice for stranded wire

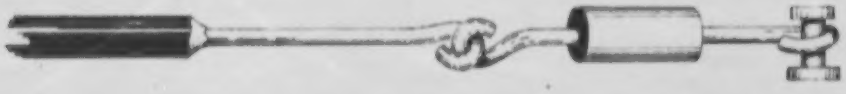
FIGURE 17



(NOTE: Simple splice is mechanically strong.)

F. Simple hook splice for solid wire component leads

FIGURE 18

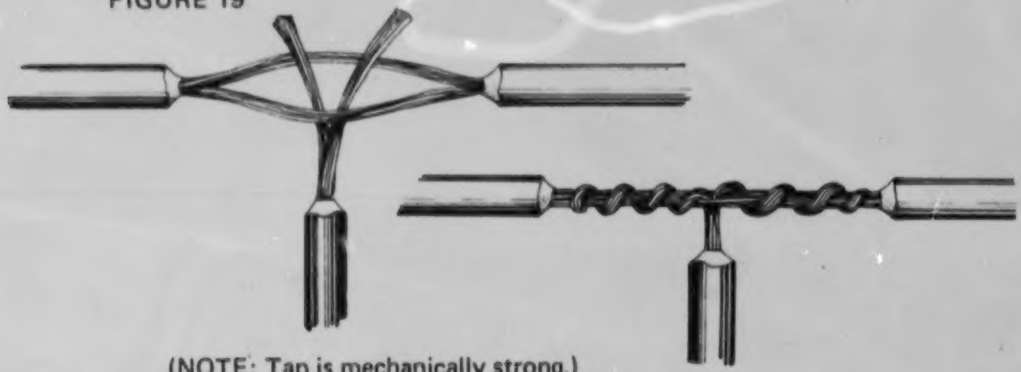


(NOTE: Hook splice is not bulky. It is quick and easy to make with short component leads where strength of the splice is not required.)

INFORMATION SHEET

G. Simple tap for stranded wires

FIGURE 19



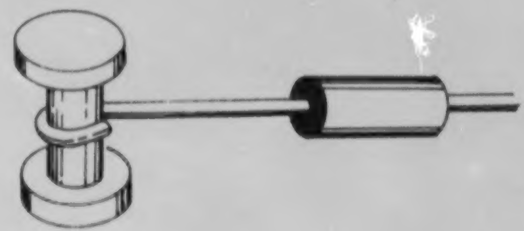
(NOTE: Tap is mechanically strong.)

IX. Correct and incorrect soldering practices (Figures 20-29)

A. Component to terminal post

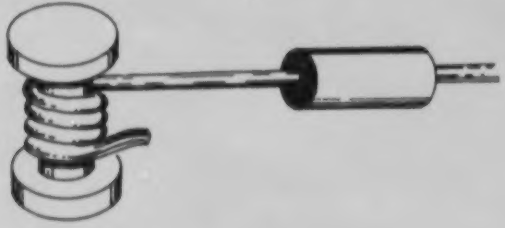
1. **Correct**--3/4 to full wrap

FIGURE 20



2. **Incorrect**--Too many wraps crowd the post

FIGURE 21



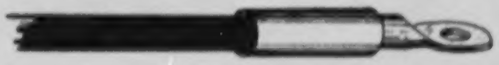
(NOTE: Strength is not a factor in small component circuits, and too many wraps make replacement during future maintenance difficult.)

INFORMATION SHEET

B. Wire to a terminal lug

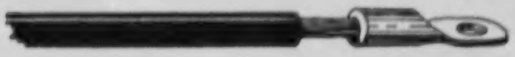
1. **Correct**--Use sleeved lugs or add a sleeve after connecting lug close to edge of insulation

FIGURE 22



2. **Incorrect**--Gap between insulation and lug

FIGURE 23

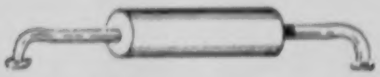


(NOTE: Gap creates a weak point where flexing forces will concentrate and cause early failure due to wire breakage.)

C. Fragile component to printed circuit board

1. **Correct**--Slight extra bends; no gap under component

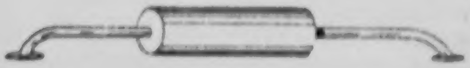
FIGURE 24



(NOTE: Extra bends allow for expansion and contraction.)

2. **Incorrect**--Taut leads

FIGURE 25



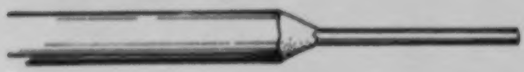
(NOTE: Taut leads do not allow for the forces of expansion and contraction due to temperature changes.)

INFORMATION SHEET

D. Heavy, high voltage insulation stripping

1. **Correct**--Tapered insulation

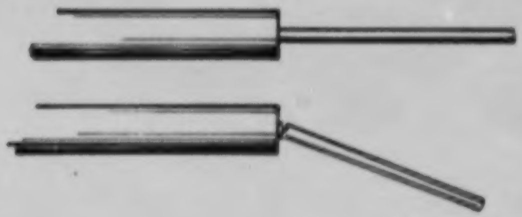
FIGURE 26



(NOTE: Tapered stripping distributes flexing across the length of the lead greatly increasing the wire's ability to flex. Any wiring subject to considerable flexing or bending should be stranded wire instead of solid wire.)

2. **Incorrect**--Straight cut insulation

FIGURE 27

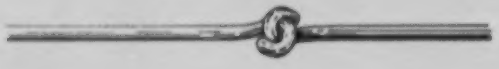


(NOTE: Straight cut insulation creates a point of force concentration during flexing of wire which can lead to eventual breaking. Wire strippers make straight cuts. This is acceptable only for flexible, thin insulation material.)

E. Hook splice prior to soldering

1. **Correct**--Snug connection

FIGURE 28

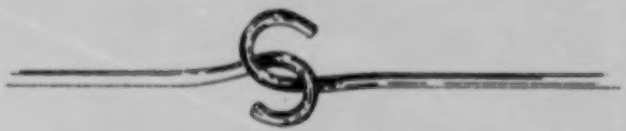


(NOTE: Snug connections ensure that solder will solidify without wires moving and creating a broken bond between the metals.)

INFORMATION SHEET

2. **Incorrect**--Loose connection

FIGURE 29



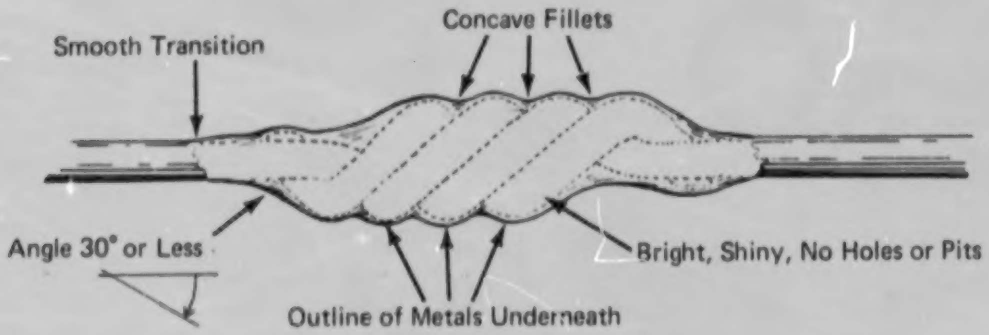
(NOTE: Loose connections will probably move during soldering, causing a cold solder joint.)

X. Good and bad characteristics of soldered joints (Figures 30-33)

A. Good soldered joint characteristics

EXAMPLE:

FIGURE 30


Concave Fillets
Smooth Transition
Angle 30° or Less
Bright, Shiny, No Holes or Pits
Outline of Metals Underneath

1. Bright
2. Shiny
3. Smooth
4. Clean
5. Complete coverage
6. Discernible outline of underlying metals

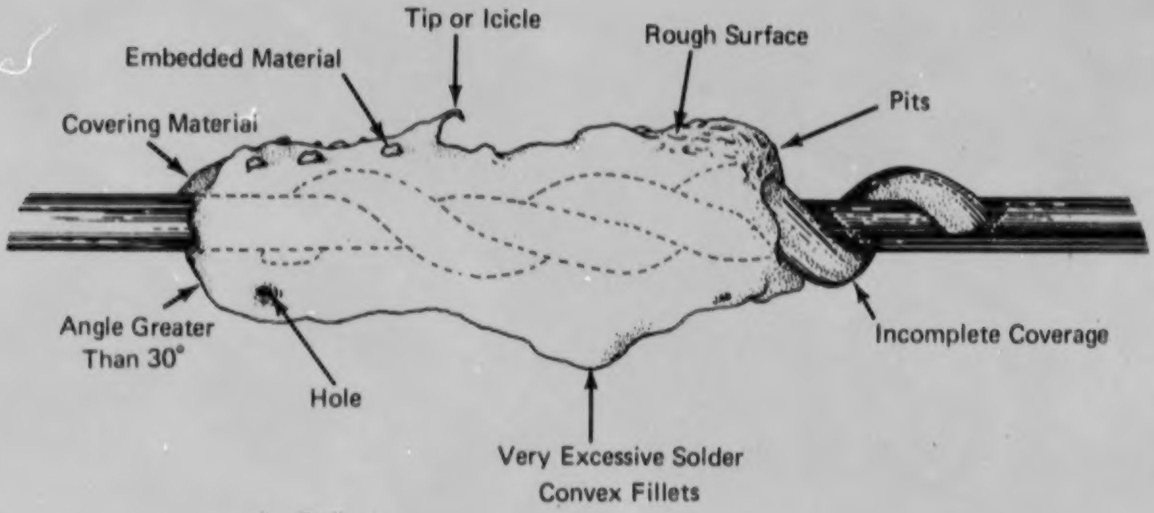
INFORMATION SHEET

7. Smooth transition at edge of solder and parent metal
8. Free of pits and holes
9. Solder tapers to an angle of approximately 30° or less
10. Concave fillets

B. Bad soldered joint characteristics

EXAMPLE:

FIGURE 31


Tip or Icicle
Embedded Material
Rough Surface
Covering Material
Pits
Angle Greater Than 30°
Hole
Incomplete Coverage
Very Excessive Solder Convex Fillets

1. Dull
2. Gritty
3. Rough surface

   (NOTE: Dull, gritty, or rough surfaces show that parts were disturbed while solder was still partially molten, thus creating a cold solder joint.)

4. Covered or embedded with foreign material

   (NOTE: Foreign material or specks appearing on the surface may indicate a large internal impurity or cavity resulting from burning material and gases in the molten solder.)

5. Incomplete coverage of joint

INFORMATION SHEET

6. Underlying metals hidden beneath huge mass of solder

7. Round, swelled edge where solder ends greater than 30°

8. Pits

9. Holes

   (NOTE: Pin holes could suggest large internal cavities created by gas pockets.)

10. Tips or icicles

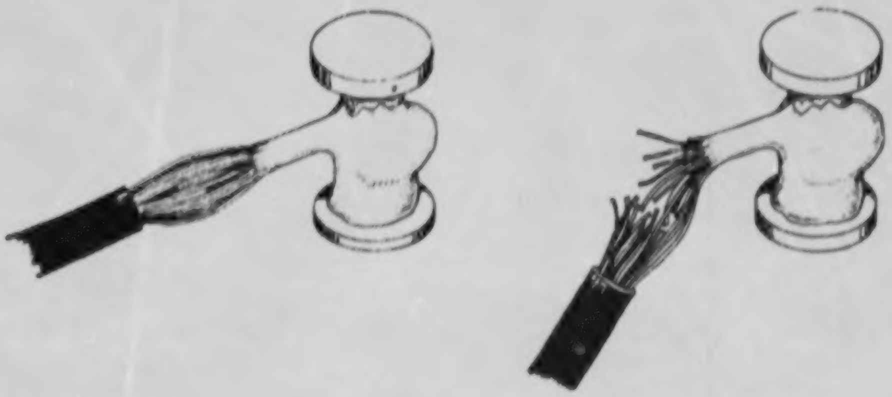
    (NOTE: Icicles are formed by excessive solder, or solder or soldering iron which is too cold.)

11. Convex fillets

12. Wicking (Figure 32)

    EXAMPLE:

FIGURE 32



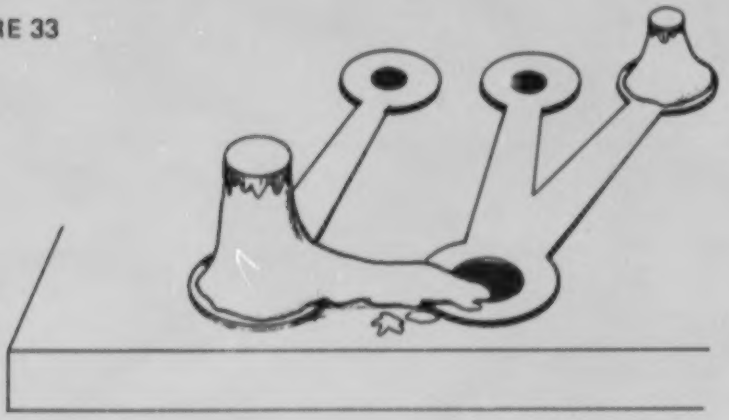
(NOTE: Wicking allows solder to flow up into stranded wire, leaving an area of high stress which will break easily. To avoid wicking, presolder the entire length of stranded wire and cover with a reinforcing sleeve.)

INFORMATION SHEET

13. Solder connecting to and short-circuiting an adjacent circuit run (Figure 33)

EXAMPLE:

FIGURE 33



XI. Chemical descriptions and interpretations

(NOTE: The *National Electrical Code* states that "because of the different characteristics of copper and aluminum, devices such as pressure terminal or pressure splicing connectors and soldering lugs shall be suitable for the material of the conductor and shall be properly installed and used." This means that the joining of copper to aluminum in a splice cannot be made with just any connector. The connectors made for aluminum or copper are marked "Cu/Al." This is an example of the many cases where electricians and technicians must interpret chemical symbols. Below are examples with their correct interpretations.)

A. Contains copper--An insulated wire has **CU** printed on it

B. Contains silver--Special solder marked **62/36/2 Ag**

C. Made of aluminum--Box of wire is marked **Al**

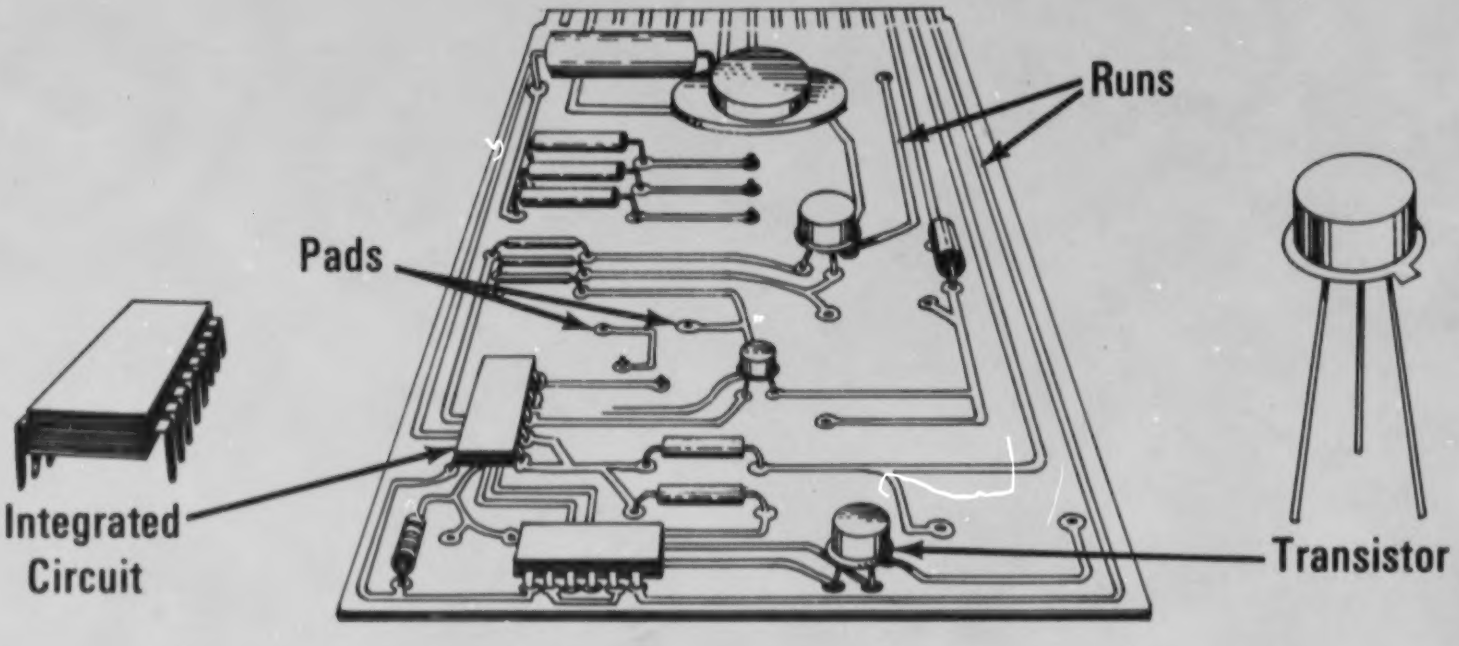
D. Contains cadmium--Spool of solder is marked **50/33/17 Cd**

E. Can be used to connect copper to aluminum--Large connector is stamped **Cu/Al**

F. Cannot be used with silver or gold--Instructions for the use of a particular flux state that it is not to be used on **Au** or **Ag** metals

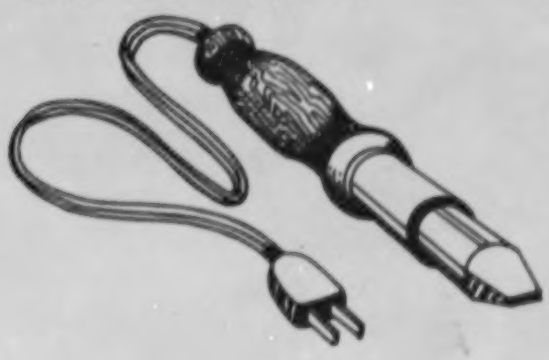
G. Can be used with copper or gold--Certain flux is specified to clean **Cu** and **Au** surfaces

Printed Circuit Board and Components

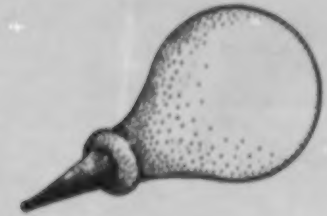

Runs
Pads
Integrated Circuit
Transistor

Soldering Tools

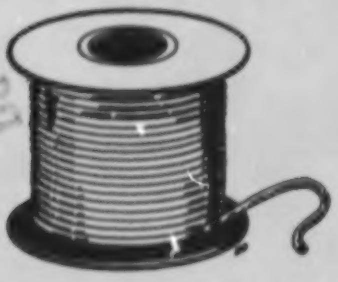
Large Soldering Iron



Desoldering Suction Bulb

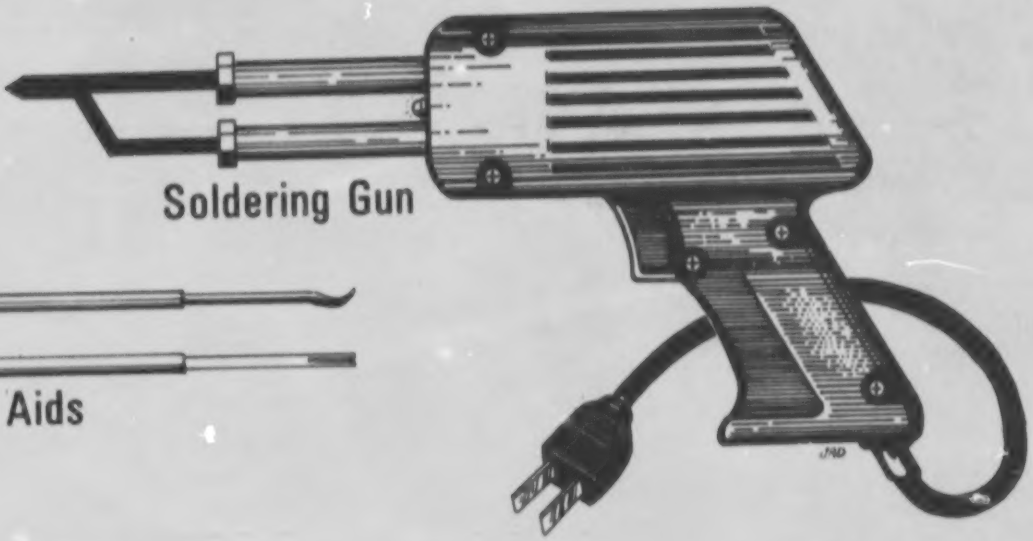


Spool of Soldering Wire

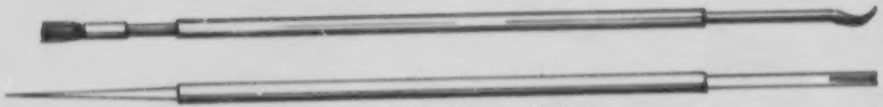


Soldering Tools

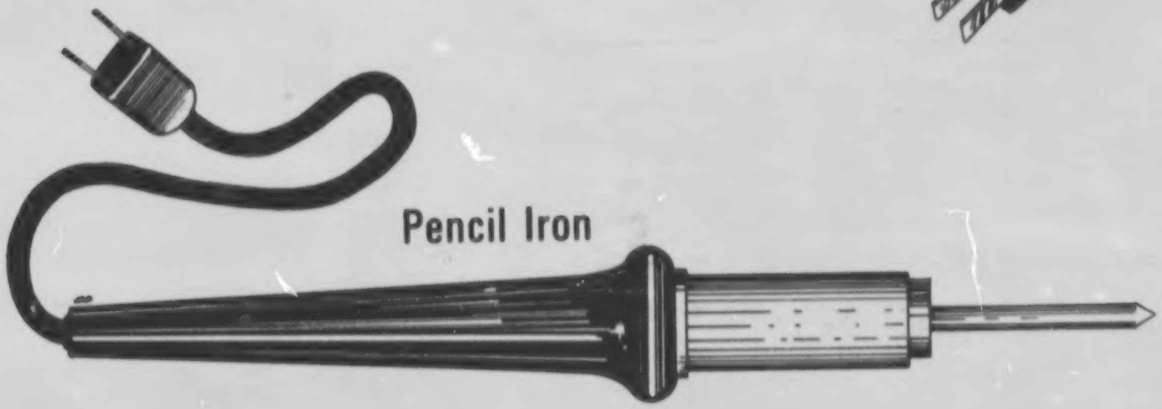
(Continued)



Soldering Gun



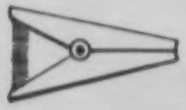
Soldering Aids



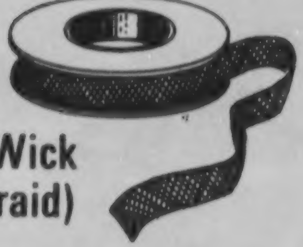
Pencil Iron

Soldering Tools

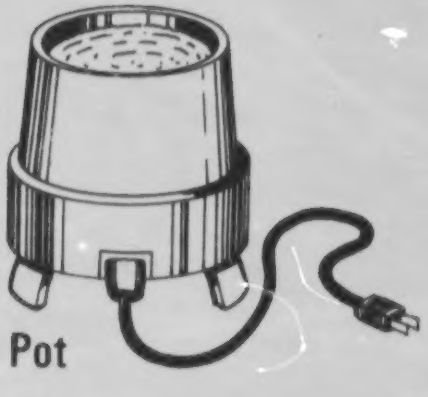
(Continued)



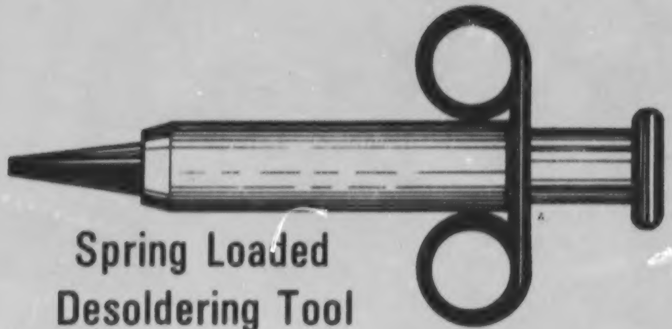
Heat Sink



Solder Wick
(Wire Braid)



Solder Pot



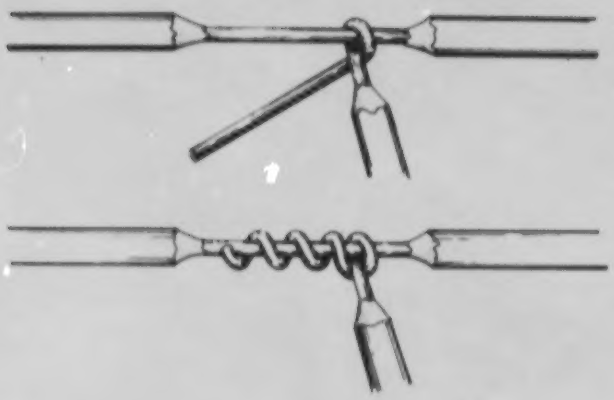
Spring Loaded
Desoldering Tool

TM #4

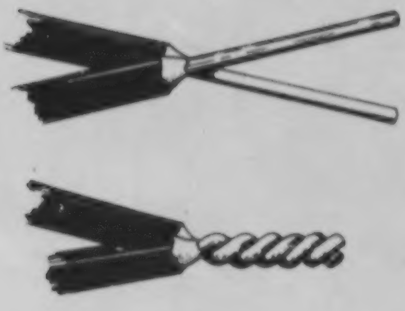
IIEE-89-F

Solid Wire Splices

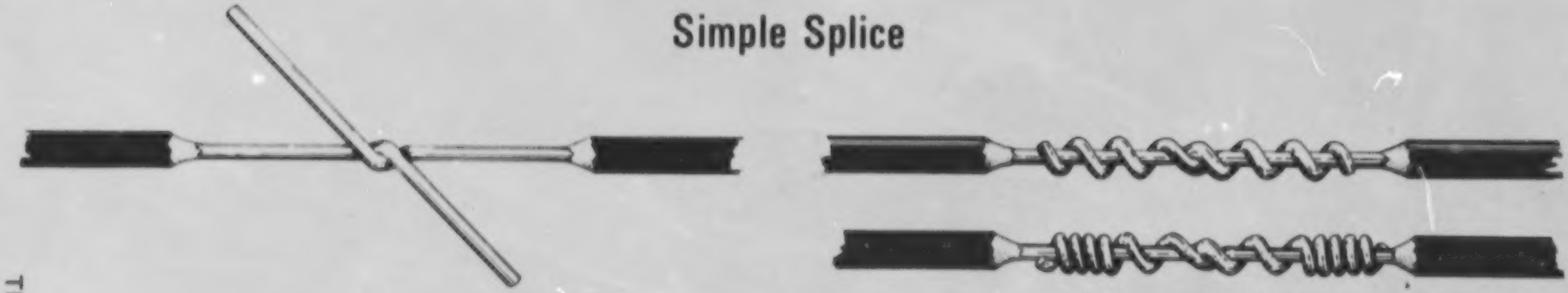
Simple Tap



Pigtail Splice



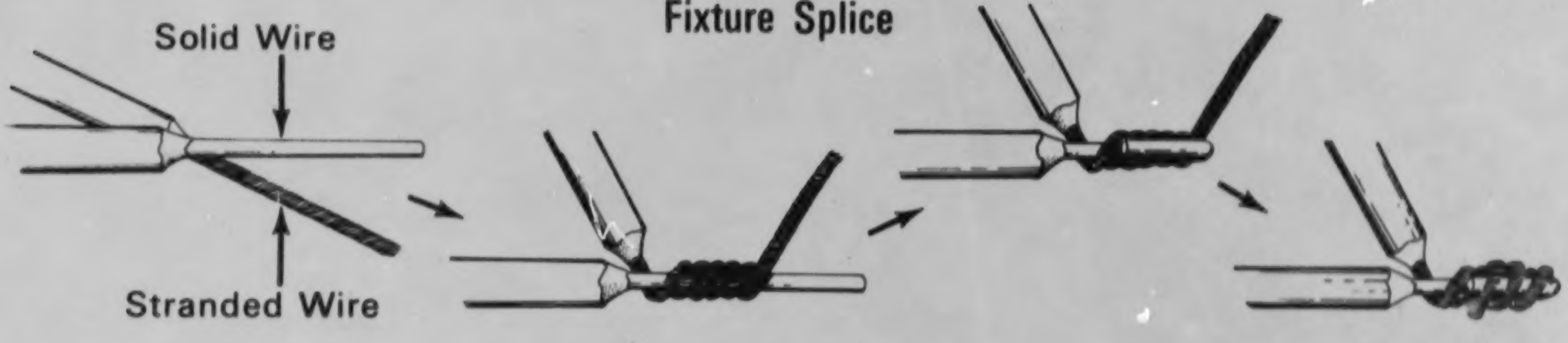
Simple Splice



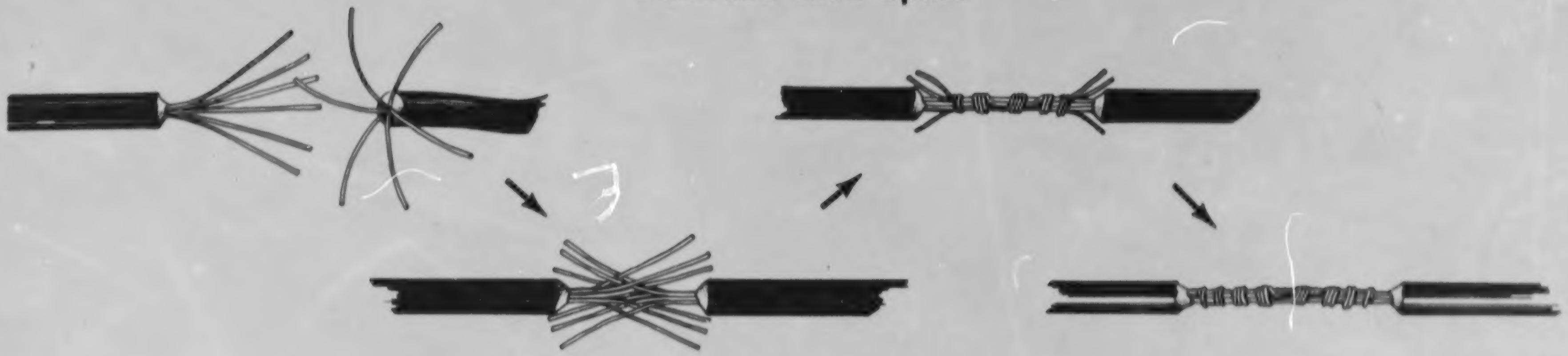
Minor Variation

Stranded Wire Splices

Fixture Splice


Solid Wire
Stranded Wire

Stranded Wire Splice

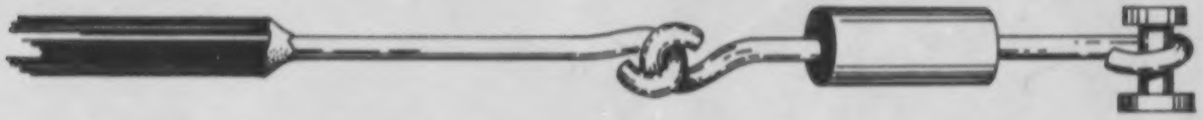


TM #6

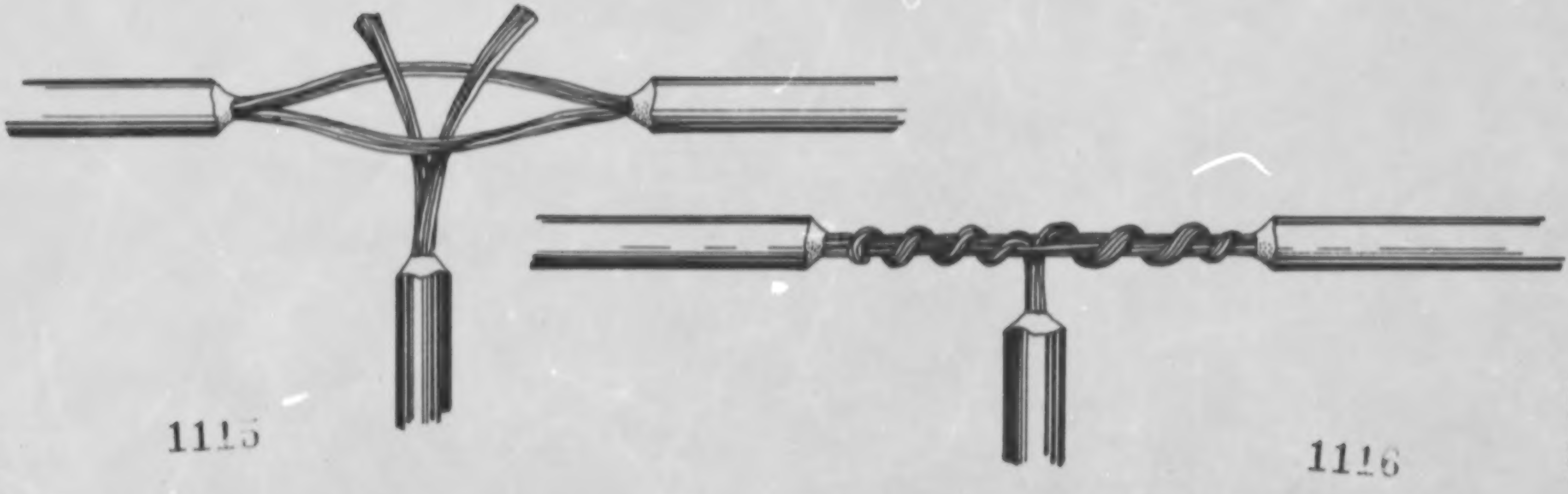
IIEE-93-F

Other Wire Splices

Simple Hook Splice



Stranded Wire Tap



1115

1116

TM #7

IIEE-95-F

SOLDERING TECHNIQUES
UNIT II

ASSIGNMENT SHEET #1--SELECT CORRECT SOLDERING TOOL SIZES

NAME________________________________ SCORE ______________

A well-equipped repair shop for electricians or electronics technicians will have soldering tools of more than one size.

Assume that you have any size tool available. Write the size, in wattage ranges, which you would use for each job described below. Do not consult lesson material.

A. Soldering an electron tube socket to a chassis

____watts

B. Soldering a large lug to a wire rated at 50 amperes

____watts

C. Soldering a replacement integrated circuit device to a printed circuit board

____watts

D. Soldering a transistor rated at 5 amperes to a printed circuit board

____watts

SOLDERING TECHNIQUES
UNIT II

ASSIGNMENT SHEET #2--SELECT METALS ACCORDING TO THEIR ABILITY TO BE SOLDERED

NAME______________________________ SCORE __________________

Solder does not readily adhere to all metals. Many metals are rarely soldered except under special conditions with special materials. It is therefore best to avoid soldering difficult metals by using other connecting techniques or by specifying different metals whenever possible.

In the examples below, choose the metal in each group that is easiest to solder, particularly under field conditions. Do not consult lesson material. Circle your choices.

A. Bronze or silver

B. Aluminum or copper

C. Brass or mild steel

D. Tin or aluminum

E. Lead or cadmium plate

F. Galvanized or chromium

G. Nickel or stainless steel

SOLDERING TECHNIQUES
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

(NOTE: Answers should be within the ranges listed.)

A. 40 to 150 watts

B. 150 to 250 watts

C. 20 watts or less

D. 20 to 40 watts

Assignment Sheet #2

A. Silver

B. Copper

C. Brass

D. Tin

E. Cadmium plate

F. Galvanized

G. Nickel

SOLDERING TECHNIQUES
UNIT II

JOB SHEET #1--PREPARE A SOLDERING IRON TIP FOR USE

I. Equipment and materials

- A. Soldering iron--Pencil iron with copper or iron-bearing tip
- B. Damp sponge
- C. Fine wire brush
- D. Fine metal file
- E. Tip cleaning flux if available (not necessary)
- F. Tinning oil if available (not necessary)
- G. 60/40 solder
- H. Soldering iron holder
- I. Safety goggles

II. Procedure

A. Put on safety goggles

B. While the soldering iron is cool, and before connecting it to the power receptacle, inspect the tip

(NOTE: Copper tips can be reshaped with a metal file.)

C. File the tip to a wedge shape without removing any more metal than is necessary

(NOTE: Iron-bearing tips should not need reshaping. If you have an iron-bearing tip that is in poor shape, ask your instructor if it should be filed or replaced. Normally iron-bearing tips are merely cleaned with a wire brush. Filing will shorten their useful life. Gold plated tips are used for particular applications and are expensive. Gold plated tips should never be filed or brushed. Cleaning is usually accomplished with a damp sponge once the tip is hot. Special cleaning fluxes are used by industry for production line tips. However, if the shank of the tip is carboned or corroded, it can be brushed with the wire brush.)

D. Place soldering iron in holder, and connect power cord to receptacle

E. Apply tinning oil, if available, to the hot tip

(NOTE: Do not put the tip into the oil container. Remove a small amount of tinning oil with a clean applicator or the tip of a clean screwdriver. Allow a drop to flow onto each surface of the hot tip's wedge.)

JOB SHEET #1

F. Apply 60/40 solder to the tip's wedged surfaces

(CAUTION: Hot solder may drip from the tip. Allow it to drip onto the wet sponge. It can burn your skin or damage clothing.)

G. Wipe excess solder from the tip onto the wet sponge

H. Disconnect the soldering iron from the receptacle, and place it in the holder to cool

(NOTE: After the iron has cooled, show it to your instructor.)

I. Put equipment and materials away

SOLDERING TECHNIQUES
UNIT II

JOB SHEET #2--SOLDER SEVEN TYPES OF WIRE SPLICES

I. Equipment and materials

A. 60/40 rosin-core solder

B. Solid copper wire--Several feet (about 2 meters) of AWG #12 or #14

C. Stranded copper wire--Several feet (about 2 meters) of AWG #16 or #18

D. Needle-nose pliers

E. Pliers with insulation stripping jaws and cutting jaws

F. Soldering tool--40 to 150 watt

G. Copy of *National Electrical Code*

H. Safety goggles

II. Procedure

A. Carefully read Article 110-14 of the *National Electrical Code*; pay particular attention to paragraph (b)

B. Put on safety goggles

C. Cut eight-inch (20 cm) lengths of the wires; remove lengths of insulation and make each of the seven splices shown in Objective XIII of the Information Sheet

D. Lay your splices neatly on the work bench and have your instructor inspect them

E. Solder all seven splices, and again ask your instructor to inspect them

(CAUTION: Soldering tools and splattering solder can produce serious burns. Return soldering tools to tool holders. Do not flip hot solder from soldering tool tips.)

F. Disconnect soldering tool and allow to cool before putting it away

G. Put equipment and materials away

SOLDERING TECHNIQUES
UNIT II

JOB SHEET #3--SOLDER AN ELECTRONIC COMPONENT TO A PRINTED CIRCUIT BOARD

I. Equipment and materials

- A. Printed circuit board--Used, obsolete, or surplus, with at least one component removed or one space blank
- B. Electronic component, resistor, capacitor, etc. of any type or condition, as specified by instructor
- C. 60/40 rosin core solder
- D. Soldering iron--20 to 40 watts
- E. Pliers--Long nose with cutting jaws (or other wire cutters)
- F. Heat sink or alligator clip

  (NOTE: Use the heat sink for practice whether the component is sensitive to heat or not.)
- G. Safety goggles

II. Procedure

- A. Put on safety goggles
- B. Clean the leads and the PC board pads if necessary
- C. Bend the leads on the component so that they pass through the holes of the printed circuit board pads
- D. Tin the soldering tool tip if necessary (Job Sheet #1)
- E. Mount the component and attach the heat sink
- F. Solder one end or one terminal of the component

  (NOTE: Have your instructor inspect your solder joint, your component mounting and your heat sink position.)
- G. Solder the other terminal(s) of the component, being careful to use the heat sink each time

  (NOTE: Do not remove heat sink until the joint cools.)

JOB SHEET #3

H. Clip the excess leads

(CAUTION: Always point leads down when clipping. The clipping action can propel the small sharp leads a considerable distance resulting in serious injury, particularily to the eyes.)

(NOTE: Have your instructor inspect your finished job.)

I. Put equipment and materials away

SOLDERING TECHNIQUES
UNIT II

JOB SHEET #4--SOLDER A TERMINAL LUG TO A WIRE

I. Equipment and materials

A. Solder type terminal lug--For a wire from AWG #18 to #8

B. Wire--Sized to terminal lug to be used; 10 inches (25 centimeters) in length

C. Soldering tool--Suitable in size for the size of connector to be soldered

D. 60/40 rosin-core solder

E. Pliers with crimpers or crimping tool suitable to crimp the lug to be used

F. Copy of *National Electrical Code*

G. Safety goggles

II. Procedure

A. Put on safety goggles

B. Remove insulation from the end of the wire just enough to allow terminal lug to mount fully and leave only a small gap at the edge of the insulation

C. Insert the wire into the lug

D. Crimp the lug to comply with the *National Electrical Code*, Article 110-14 paragraph (b)

E. Once the mechanical connection is made, solder the lug to the wire

(NOTE: Have your instructor inspect your work.)

F. Put equipment and materials away

SOLDERING TECHNIQUES
UNIT II

JOB SHEET #5--SOLDER A HEAT-SENSITIVE COMPONENT TO A PRINTED CIRCUIT BOARD

I. Equipment and materials

A. Soldering iron--From 15 to 30 watts

B. Heat sink, or large alligator clip

C. Solder--60/40 or lower temperature type

D. Printed circuit board--With position available to mount any electronic component

(NOTE: The PC board for this job sheet may be used, defective, or any board available.)

E. Any heat-sensitive electronic component

F. Soldering aid

G. Long-nose pliers or needle-nose pliers

H. Diagonal cutting pliers

I. Safety goggles

II. Procedure

A. Put on safety goggles

B. Clean PC board pads with the soldering aid until they are bright and shiny

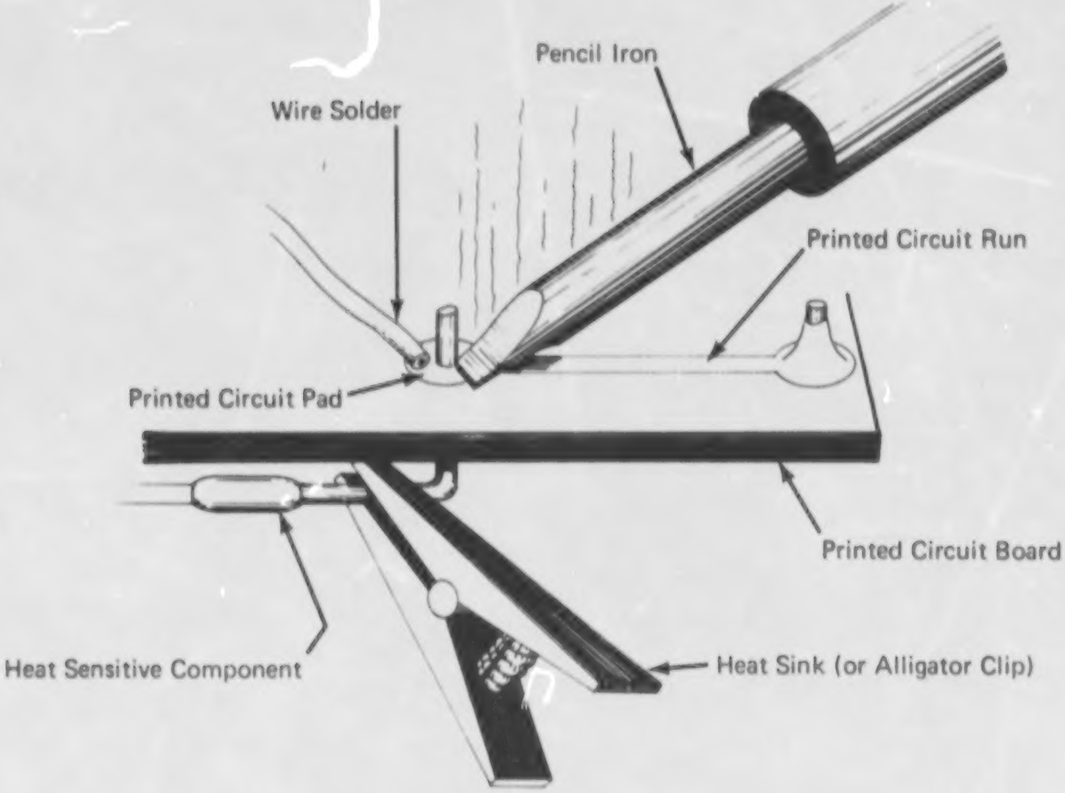
C. Inspect the soldering iron tip

(NOTE: Clean and reshape, if necessary, following procedures in Job Sheet #1.)

JOB SHEET #5

D. Use the pliers to bend the component leads to fit into the PC board pads as shown in Figure 34

FIGURE 34


Pencil Iron
Wire Solder
Printed Circuit Run
Printed Circuit Pad
Printed Circuit Board
Heat Sensitive Component
Heat Sink (or Alligator Clip)

E. Clean component leads where solder will be applied

F. Attach the heat sink or alligator clip *between* the component and the point where heat will be applied

G. Position the component on the PC board

(NOTE: Heat-sensitive components are mounted in various ways depending upon the type of component being mounted. Check with the instructor before positioning component.)

JOB SHEET #5

H. Solder the component leads to the pads by touching the tip to both the pad and the lead

(NOTE: The point of contact and the dwell time is determined by the relative sizes of the metals to be joined. When soldering a small heat-sensitive component to a large terminal post or lug, for example, the iron should first be placed on the lug for a few seconds to pre-heat it before being applied to the junction of the lead and the lug. For extremely heat-sensitive components, a lower temperature solder, such as *50/33/17 Cd*, may be used. Dwell time on a heat-sensitive component should not exceed 10 seconds. Apply the solder and quickly remove the iron. Applying a little solder to the tip before touching the component lead increases heat transfer and helps reduce the time of contact.)

I. Leave the heat sink attached until the solder joint cools

J. Clip the excess component leads projecting from the solder joints

(CAUTION: Turn the PC board down so that when the leads are clipped the ends are not projected into yours or any bystander's eyes. The clipping action causes the leads to be propelled and care should be taken.)

(NOTE: Show your work to the instructor.)

K. Put equipment and materials away

SOLDERING TECHNIQUES
UNIT II

TEST

NAME ____________________ SCORE ____________

1. Match terms associated with soldering techniques to their correct definitions. Write the correct numbers in the blanks. Definitions are continued on the next page.

_____a. Type of flux used in electrical and electronic soldering applications; filled-in core of solder ("rosin-core solder"), which dispenses as the solder melts; non-corrosive and non-conductive

_____b. Strip of conductor on a printed circuit board

_____c. 1/16-inch plastic, fiberglass, or phenolic board upon which copper strips interconnect between mounted components

_____d. Junction of two or more metals fused with solder

_____e. Solution that cleans metals before or during soldering, or chemically acts to aid the fusion process

_____f. Round terminal connection point on a printed circuit board where component lead wires are attached

_____g. Soft metal alloy of tin and lead used for plating or fusing metals together

_____h. Solid-state device common to modern circuitry varying in size and function; usually characterized by three leads

_____i. Solid-state electronic component comprised of many components miniaturized into a single, small package; usually characterized by having from eight to sixteen leads

_____j. Flow of solder under the insulation of covered wire

_____k. To unite (connect) two wires to form a continuous length

_____l. Solder-welding two edges at right angles

1. Solder
2. Flux
3. Rosin
4. Printed circuit board
5. Run
6. Pad
7. Solder joint
8. Intergrated circuit device
9. Transistor
10. Fillet
11. Wicking
12. Galvanized
13. Convex
14. Splice
15. Concave
16. Phenolic board

TEST

______m. Having a curved form which bulges outward

______n. Having a curved form which bulges inward

______o. Surface on which zinc has been deposited by the process of hot dipping or electroplating

______p. Plastic material (thermosetting resin) which becomes permanently hardened when subjected to heat; originally known as Bakelite®; used for printed circuit board construction

2. Match symbols associated with soldering techniques to their correct definitions. Write the correct numbers in the blanks.

______a. Lead

______b. Tin

______c. Nickel

______d. Aluminum

______e. Printed circuit

______f. Silver

______g. Gold

______h. Copper

______i. Cadmium

______j. Watt

1. Sn
2. Pb
3. Ag
4. Al
5. Au
6. Cd
7. PC
8. W
9. Cu
10. Ni

3. State two primary purposes for solder in electrical applications.

a. ____

____

b. ____

____

TEST

4. Match general soldering tool sizes to their correct applications. Write the correct numbers in the blanks.

_____a. For use with circuits containing components rated less than 1/2-watt, integrated circuit devices, and circuits rated less than 1 ampere

_____b. For use with transistor circuits involving components rated 1/2-watt or larger and their associated printed circuit boards, and circuits rated 1 to 10 amperes

_____c. For use with large connectors and circuits rated 30 to 50 amperes or greater

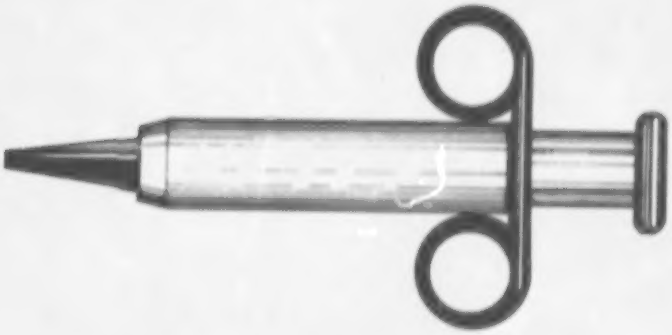
_____d. For use with vacuum tube circuits, connectors, and circuits rated 10 to 30 amperes

1. 150 to 250 watts
2. 40 to 150 watts
3. 20 to 40 watts
4. 20 watts or less

5. Identify soldering tools and materials. Write the correct names in the blanks below each tool.

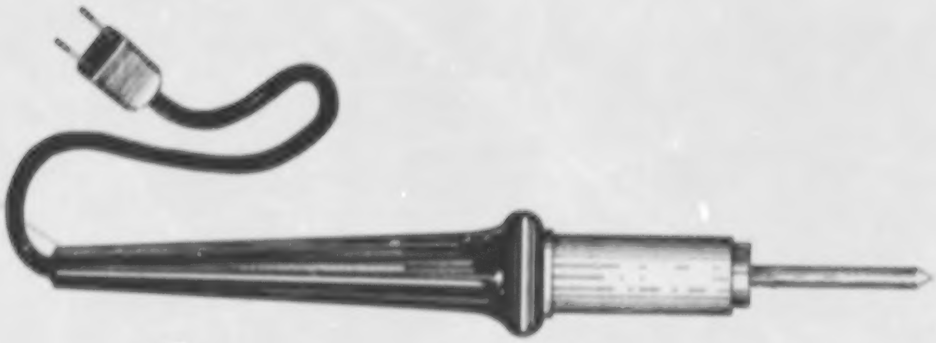
Large soldering iron
Desoldering suction bulb
Spool of solder wire
Soldering gun
Pencil iron

Soldering aids
Heat sink
Solder wick (wire braid)
Solder pot
Spring-loaded desoldering tool

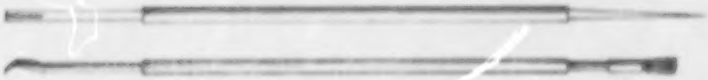


a. ____

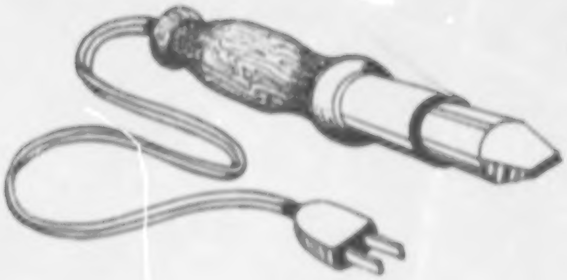
TEST



b. ______________________________

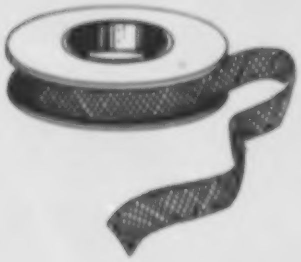


c. ______________________________

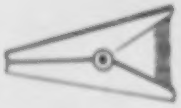


d. ______________________________

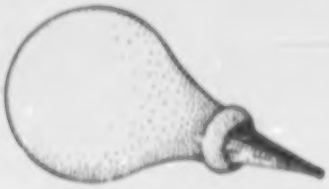
TEST



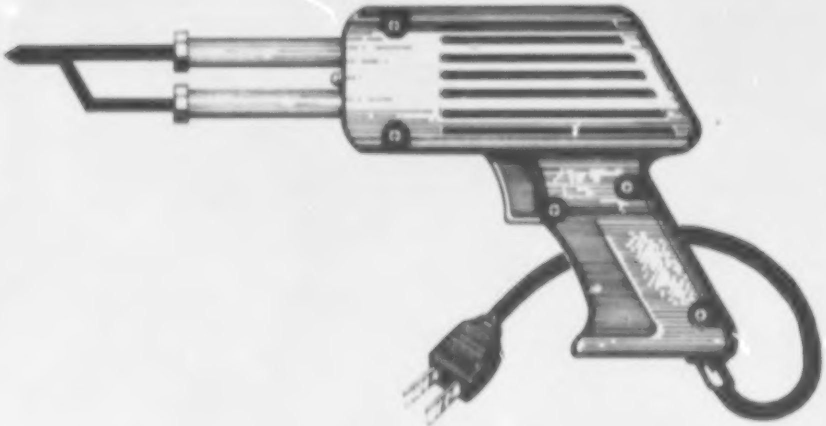
e. ______________________________



f. ______________________________

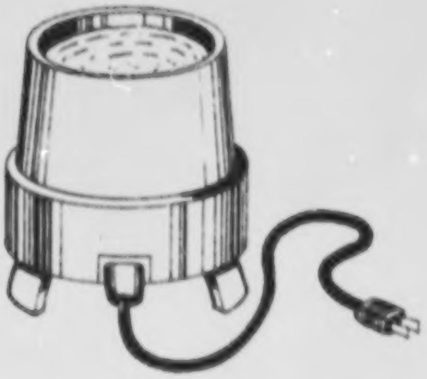


g. ______________________________

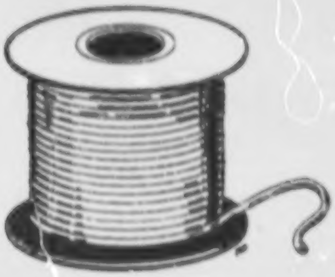


h. ______________________________

TEST



i. ______________________________



j. ______________________________

6. Classify metals according to their ability to be soldered. Write an "R" for metals that solder readily, an "RW" for metals that solder reasonably well, a "D" for those difficult to solder, and an "ED" for those extremely difficult to solder.

_____ a. Lead

_____ b. Chromium

_____ c. Copper

_____ d. Nickel

_____ e. Gold

_____ f. Galvanized

_____ g. Aluminum

_____ h. Mild steel

_____ i. Stainless steel

_____ j. Platinum

_____ k. Tin

_____ l. Bronze

_____ m. Nickel-tin alloy

_____ n. Silver

_____ o. Brass

_____ p. Cadmium plate

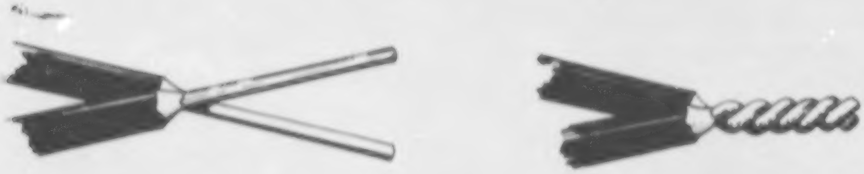
TEST

7. Name the solder type used for most electrical applications.

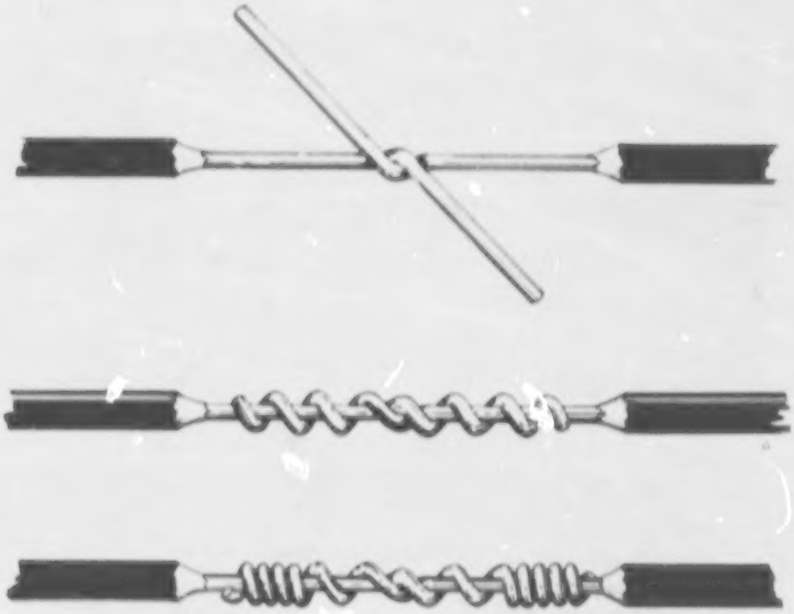
____

____

8. Label common wire splices. Write the correct names in the blanks below each spice.

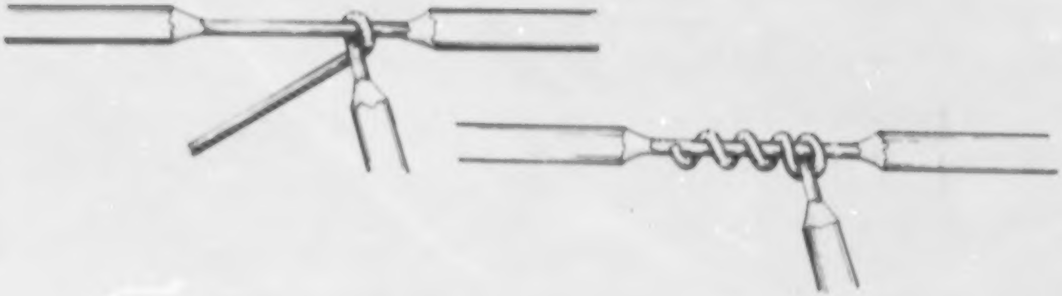


a. ______________________

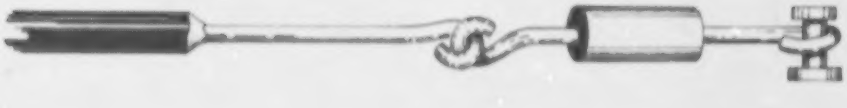


b. ______________________

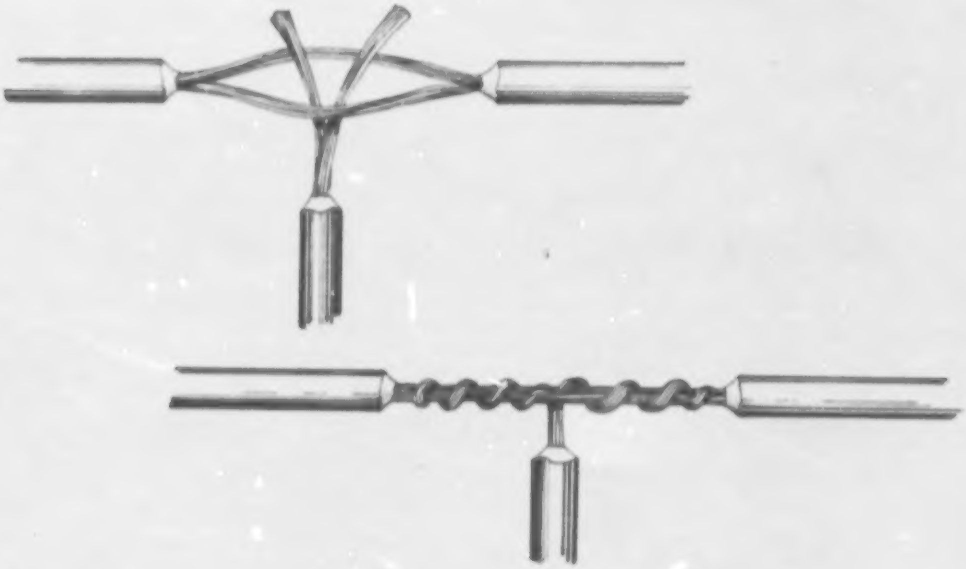
TEST



c. ______________________________

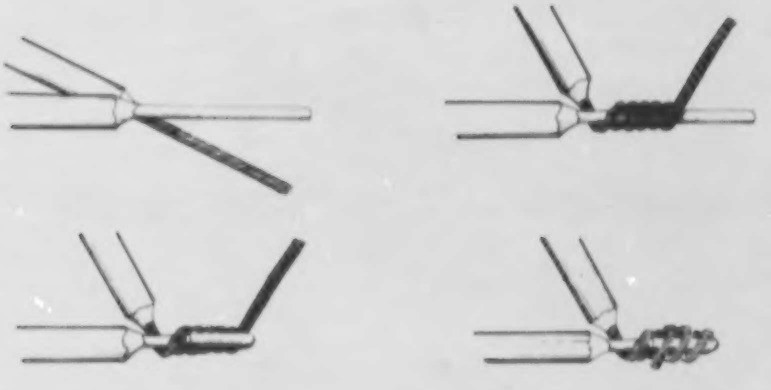


d. ______________________________

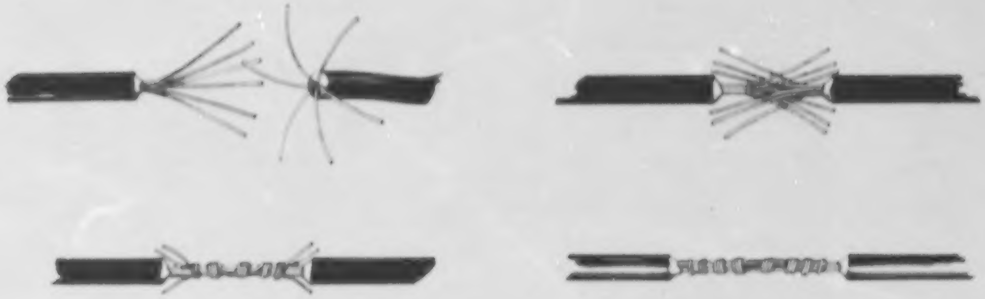


e. ______________________________

TEST



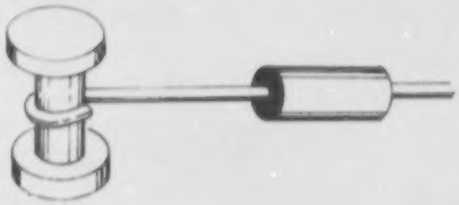
f. ________________________________



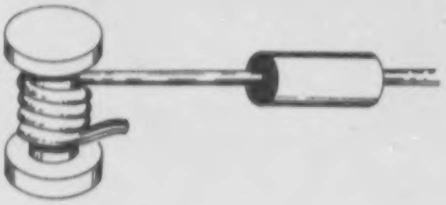
g. ________________________________

9. Distinguish between correct and incorrect soldering practices. Write "correct" in the blanks below proper soldering practices, and "incorrect" in the blanks below improper soldering practices.

   a. Component to terminal posts



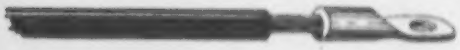
1) ____________________________



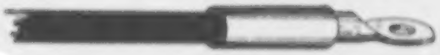
2) ____________________________

TEST

b. Wire to terminal lug

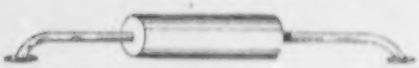


1) ____________________

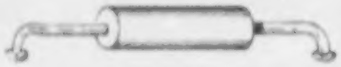


2) ____________________

c. Fragile component to printed circuit board

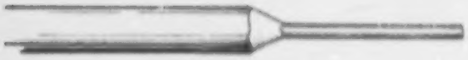


1) ____________________

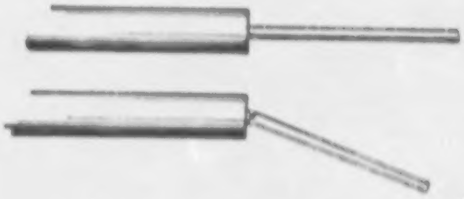


2) ____________________

d. Heavy, high voltage insulation stripping

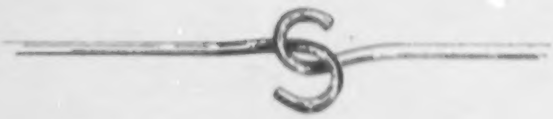


1) ____________________

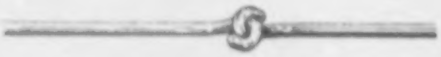


2) ____________________

e. Hook splice prior to splicing



1) ____________________



2) ____________________

TEST

10. Distinguish between good and bad characteristics of soldered joints. Write a "G" for good characteristics and a "B" for bad characteristics.

_____ a. Convex fillets

_____ b. Tips or icicles

_____ c. Bright

_____ d. Holes

_____ e. Shiny

_____ f. Smooth

_____ g. Pits

_____ h. Clean

_____ i. Round, swelled edge where solder ends greater than 30°

_____ j. Complete coverage

_____ k. Underlying metals hidden beneath huge mass of solder

_____ l. Incomplete coverage of joint

_____ m. Covered or embedded with foreign material

_____ n. Discernible outline of underlying metals

_____ o. Smooth transition at edge of solder and parent metal

_____ p. Free of pits and holes

_____ q. Rough surface

_____ r. Solder tapers to an angle of approximately 30° or less

_____ s. Gritty

_____ t. Dull

_____ u. Concave fillets

_____ v. Solder connecting to and short-circuiting an adjacent circuit run

_____ w. Wicking

TEST

11. Match chemical interpretations to their correct descriptions. Write the correct numbers in the blanks.

_____a. Instructions for the use of a particular flux state that it is not to be used in **Au** or **Ag** metals

_____ b. Spool of solder is marked **50/33/17 Cd**

_____ c. Box of wire is marked **Al**

_____ d. An insulated wire has **Cu** printed on it

_____ e. Large connector is stamped **Cu/Al**

_____f. Certain flux is specified to clean **Cu** or **Au** surfaces

_____ g. Special solder marked **62/36/2 Ag**

1. Contains copper
2. Contains silver
3. Made of aluminum
4. Contains cadmium
5. Can be used to connect copper to aluminum
6. Cannot be used with silver or gold
7. Can be used with copper or gold

(NOTE: Test questions 12-14 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

12. Select correct soldering tool sizes.

13. Select metals according to their ability to be soldered.

14. Demonstrate the ability to

    a. Prepare a soldering iron tip for use.

    b. Solder seven types of wire splices.

    c. Solder an electronic component to a printed circuit board.

    d. Solder a terminal lug to a wire.

    e. Solder a heat-sensitive component to a printed circuit board.

SOLDERING TECHNIQUES
UNIT II

ANSWERS TO TEST

1. a. 3
   b. 5
   c. 4
   d. 7
   e. 2
   f. 6
   g. 1
   h. 9
   i. 8
   j. 11
   k. 14
   l. 10
   m. 13
   n. 15
   o. 12
   p. 16

2. a. 2
   b. 1
   c. 10
   d. 4
   e. 7
   f. 3
   g. 5
   h. 9
   i. 6
   j. 8

3. Answer should include any two of the following
   a. Makes connections with virtually no resistance to electrical current flow
   b. Prevents corrosion of conductors, connections, and parts
   c. Makes connections mechanically stronger
   d. Seals containers to keep out dust and moisture

4. a. 4
   b. 3
   c. 1
   d. 2

ANSWERS TO TEST

5. a. Spring-loaded desoldering tool
   b. Pencil iron
   c. Soldering aids
   d. Large soldering iron
   e. Solder wick (wire braid)
   f. Heat sink
   g. Desoldering suction bulb
   h. Soldering gun
   i. Solder pot
   j. Spool of solder wire

6. a. RW
   b. ED
   c. R
   d. RW
   e. R
   f. D
   g. D
   h. D
   i. ED
   j. R
   k. R
   l. RW
   m. D
   n. R
   o. RW
   p. R

7. 60% tin and 40% lead with rosin core

8. a. Pigtail splice for solid wire
   b. Simple splice for solid wire
   c. Simple tap for solid wire
   d. Simple hook splice for solid wire component leads
   e. Simple tap for stranded wires
   f. Fixture splice for solid wire and standard wire connection
   g. Simple splice for stranded wire

ANSWERS TO TEST

9. a. Component to terminal posts
    1) Correct
    2) Incorrect

   b. Wire to terminal lug
    1) Incorrect
    2) Correct

   c. Fragile component to printed circuit board
    1) Incorrect
    2) Correct

   d. Heavy, high voltage insulation stripping
    1) Correct
    2) Incorrect

   e. Hook splice prior to splicing
    1) Incorrect
    2) Correct

10. a. B
    b. B
    c. G
    d. B
    e. G
    f. G
    g. B
    h. G
    i. B
    j. G
    k. B
    l. B
    m. B
    n. G
    o. G
    p. G
    q. B
    r. G
    s. B
    t. B
    u. G
    v. B
    w. B

11. a. 6
    b. 4
    c. 3
    d. 1
    e. 5
    f. 7
    g. 2

12. Evaluated to satisfaction of instructor

13. Evaluated to satisfaction of instructor

14. Performance skills evaluated to satisfaction of instructor

PRINTED CIRCUIT BOARDS
UNIT III

UNIT OBJECTIVES

After completing this unit, the student should be able to construct a printed circuit board, replace defective components, and repair conductor problems, including those caused by broken printed circuit boards. This knowledge will be shown by completing an assignment sheet, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with printed circuit boards to their correct definitions.
2. Match abbreviations associated with printed circuit boards to their correct definitions.
3. Identify symbols associated with printed circuit boards.
4. List materials needed to fabricate a printed circuit board.
5. List materials used in constructing a printed circuit board.
6. Name types of printed circuit boards.
7. Distinguish between mechanical and chemical methods of transferring circuit layout to a single-sided, printed circuit board.
8. Arrange in order steps in transferring circuit layout to a double-sided, printed circuit board.
9. Select from a list specifications for mounting components on a printed circuit board.
10. Select from a list conformal coating characteristics of a printed circuit board.
11. List common types of printed circuit board connectors.
12. Select from a list advantages and disadvantages of common printed circuit board connectors.
13. Discuss characteristics of mounting printed circuit board assemblies.
14. List design and layout procedures for a printed circuit board.
15. Arrange in order manual steps in fabricating a printed circuit board.

OBJECTIVE SHEET

16. Select from a list advantages of printed circuit boards.
17. List problems that may occur in printed circuit boards.
18. Match methods of repairing printed circuit boards to their correct descriptions.
19. Describe methods of removing a bad component from a printed circuit board.
20. Explain the procedure for replacing a heat-sensitive component.
21. Design a circuit layout for a printed circuit board.
22. Demonstrate the ability to
    a. Transfer a circuit layout to a printed circuit board.
    b. Prepare a printed circuit board for etching.
    c. Etch a printed circuit board.
    d. Install components on a printed circuit board.
    e. Make continuity checks of a printed circuit board.
    f. Make printed circuit board repairs.

PRINTED CIRCUIT BOARDS
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information, assignment, and job sheets.

   C. Make transparencies.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Show examples of printed circuit boards in various stages of completion and explain fabrication process.

   H. Demonstrate the three methods of repairing printed circuit boards.

   I. Give test.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency mas

      1. TM #1--Edge Connector

      2. TM #2--Pin Connector

      3. TM #3--PC Board Mounting Assembly

      4. TM #4--PC Board Layout

      5. TM #5--PC Board Repair Procedures

   E. Assignment Sheet #1--Design a Circuit Layout for a Printed Circuit Board

   F. Answers to assignment sheet

   G. Job sheets

      1. Job Sheet #1--Transfer a Circuit Layout to a Printed Circuit Board

      2. Job Sheet #2--Prepare a Printed Circuit Board for Etching

SUGGESTED ACTIVITIES

3. Job Sheet #3--Etch a Printed Circuit Board

4. Job Sheet #4--Install Components on a Printed Circuit Board

5. Job Sheet #5--Make Continuity Checks of a Printed Circuit Board

6. Job Sheet #6--Make Printed Circuit Board Repairs

H. Test

I. Answers to test

III. Unit references

A. Grob, Bernard. *Basic Electronics*. 4th ed. New York: McGraw-Hill Book Company, 1977.

B. *Industrial Electronics Training Program: Semiconductors, Lesson IV*. Barrington, Illinois: TPC Training Systems, Division of Technical Publishing Company, 1977.

C. Shrader, Robert L. *Electronic Communication*. 3rd ed. New York: McGraw-Hill Book Company, 1975.

PRINTED CIRCUIT BOARDS
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Soldering aid--Tool with a fork, hook, brush, knife, or reamer; used when soldering or desoldering conductors

B. Etching tray--Tray used to rinse excess copper from printed circuit boards

(NOTE: Etching trays are usually made of plastic and hold a solution of ferric chloride called *etchant*.)

C. Ferric chloride--Solution used to remove excess copper coating from printed circuit boards

(CAUTION: Ferric chloride will damage metal surfaces and stain clothes, as well as stain and irritate skin.)

D. Heat sink--Metal tool used to radiate heat away from the components when soldering or desoldering

EXAMPLES: Alligator clips, hemostats

E. Phenolic board--Plastic material (thermosetting resin) which becomes permanently hardened when subjected to heat; originally known as Bakelite® ; used for printed circuit board construction

F. Photoetching--Process where circuit is drawn on paper, photographed, and then photographically transferred onto phenolic board

G. Printed circuit board--Plastic, phenolic, or fiberglass material, 1/16 to 1/18 of an inch thick, onto which a circuit has been printed with copper or silver conductive material, and electronic components have been installed

H. Printed wiring--Pattern of conductors mounted on an insulated base material to provide the interconnection of components to make an electrical circuit

I. Resist ink--Liquid deposited onto a copper-clad material to prevent copper conductive material from being etched away

J. Soldering iron--Tool having a heating element to melt solder

(NOTE: A 25 to 35-watt soldering iron is used for printed circuit boards.)

K. Clad--Conductive material bonded to printed circuit board

L. Single-clad--Conductive material on only one side of a circuit board

M. Extender board--Adapter that increases connector length to make the printed circuit board visible for in-circuit work

INFORMATION SHEET

N. Jig--Adjustable clamping device mounted on a base or stand to hold a printed circuit board during repair

(NOTE: A jig is also referred to as a *board holding fixture*.)

O. Wicking--Process using wire braid to remove solder from solder connections; flow of solder under the insulation of covered wire

P. PC board handles--Device attached to printed circuit boards; used to remove board from mounting

Q. Board ejector--Plastic wedge attached to printed circuit boards; used to remove tightly clamped circuit boards

R. Solder sucker--Tool which draws hot solder from an electronic connection; may be operated by hand or by electricity

S. Wire braid--Very fine wire braid used to remove solder from solder points by placing solder braid between soldering iron and solder, thus soaking up solder and leaving the connection bare

T. Wave soldering--Process in which printed circuit board components are all placed on the circuit board, which is then moved over a wave of molten solder, thus soldering all connections simultaneously

U. Ammonium persulfate--Chemical solution which removes excess copper coating from printed circuit boards

II. Abbreviations associated with printed circuit boards

A. **PC**--Printed circuit

B. **PCB**--Printed circuit board

C. **PW**--Printed wiring

D. **R**--Resistor

E. **C**--Capacitor

F. **L**--Inductor

G. **Q**--Transistor

H. **D**--Diode

I. **V**--Vacuum tube

J. **T**--Transformer

K. **TB**--Terminal board

L. **IC**--Integrated circuit

M. **LED**--Light-emitting diode

INFORMATION SHEET

N. TP--Test point

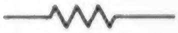
O. F--Fuse

P. S or Sw--Switch

III. Symbols associated with printed circuit boards (Figures 1-11)

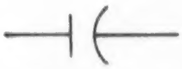
A. Resistor

FIGURE 1



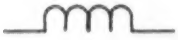
B. Capacitor

FIGURE 2



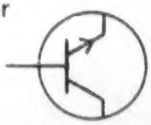
C. Inductor

FIGURE 3



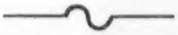
D. Transistor

FIGURE 4



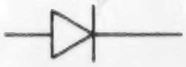
E. Fuse

FIGURE 5



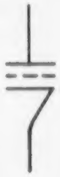
F. Diode

FIGURE 6



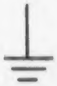
G. Tube

FIGURE 7



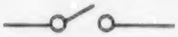
H. Ground

FIGURE 8



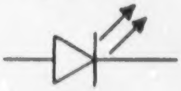
I. Switch

FIGURE 9



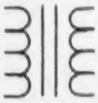
J. Light-emitting diode

FIGURE 10



K. Transformer

FIGURE 11



INFORMATION SHEET

IV. Materials needed to fabricate a printed circuit board

A. Board with conductive coating

B. Resist ink

C. Resist symbols

D. Resist tape

E. Ferric chloride or equivalent chemical

F. Etching tray

G. 25 to 35-watt soldering iron

H. Drill motor and drills, sized according to conductor diameter of components

I. Various components for circuit being built

EXAMPLES: Resistors, capacitors, diodes, transistors, integrated circuits

J. Circuit layout or design to be placed on printed circuit board

V. Materials used in constructing a printed circuit board

A. Plastic

B. Fiberglass

C. Paper-base phenolic

D. Plastic phenolic

E. Glass epoxy

(NOTE: Thicknesses of printed circuit boards normally range from 0.063 inches to 0.125 inches. Thicker boards are mechanically stronger, but they are more expensive, heavier, take up more space, and are more difficult to cut and drill.)

VI. Types of printed circuit boards

A. Flexible boards

(NOTE: These boards are generally thin, plastic boards that bend and twist without damage. They are used for wiring harnesses and are not as common as rigid circuit boards.)

B. Rigid boards

(NOTE: These boards provide an insulating mount for printing wiring and additional circuit components. They can also withstand shock, vibrations, and changes in humidity and temperature. They are usually constructed of paper-base phenolic or glass epoxy.)

INFORMATION SHEET

C. Single-sided

(NOTE: These boards have the conductive wiring pattern on only one side of the board.)

D. Double-sided

(NOTE: These boards have the conductive wiring pattern on both sides of the board. Holes through the board connect the two patterns and allow for complex wiring patterns.)

E. Laminated

VII. Methods of transferring circuit layout to a single-sided printed, circuit board

A. Mechanical techniques

1. Stamping

(NOTE: A die with a raised outline of the wiring pattern stamps the pattern from thin copper foil. This foil is then bonded to the insulating board.)

2. Spraying

(NOTE: A stencil of the wiring pattern is placed over the insulating board, and molten copper is sprayed on the board.)

3. Embossing

(NOTE: Copper foil is bonded to the insulating board. A die with a raised image of the circuit pattern presses the pattern into the base, leaving excess raised copper which is then mechanically removed.)

B. Chemical techniques

1. Silk-screening

(NOTE: A fine screen of silk or stainless steel is coated with wax in areas where copper is not wanted. The screen is then stretched above the foil-covered, printed circuit board. A chemical resist ink passes through the unwaxed areas and covers the foil where conductors will remain.)

2. Photographic

(NOTE: The copper area of the printed circuit board is coated with a chemical that hardens upon contact with light. Then, a photographic negative is placed over the copper foil, light is applied, and the exposed copper hardens. Etching solution is then used to remove all excess copper foil which has not hardened.)

INFORMATION SHEET

3. Printed

(NOTE: An ink image of the conductor pattern is printed on the foil coating of the printed circuit board. An asphalt powder is dusted over the conductor area, forming a hard film over the printed pattern.)

VIII. Steps in transferring circuit layout to a double-sided, printed circuit board

(NOTE: Methods outlined for a single-sided printed circuit board were used in the past, and holes were drilled through the boards for connections. The plate-through-hole process deposited copper on the board rather than etching excess copper from the board.)

A. Design two layouts, one for each side

B. Drill holes, as indicated by layouts

C. Apply negative resist to areas indicated by layouts

(NOTE: Resist prevents copper from being deposited where it is not wanted.)

D. Electro-deposit copper on the board and on all sides of the holes

E. Strip away resist, leaving the circuit pattern on both sides of the printed circuit board

IX. Specifications for mounting components on a printed circuit board

A. Components should be mounted directly on printed circuit board or as close to board as possible

B. Component markings should be clearly visible

C. Heavy components should have additional support against shock and vibration

D. Sockets and connectors should be mounted as close to board as possible

(NOTE: This will help in removing and replacing components so they do not break.)

E. Heat sinks should always be used for heat-sensitive components

X. Conformal coating characteristics of a printed circuit board

A. Placed over the complete printed circuit board assembly

B. Made from silicone, epoxy, polyurethane, varnish, or lacquer dissolved in a solvent

INFORMATION SHEET

C. Leaves thin, rough film over the printed circuit board, due to solvent evaporating

(NOTE: Printed circuit board coatings are used to protect the assembly from moisture, corrosion, and vibration. The coating is also a form of protection for personnel.)

XI. Common types of printed circuit board connectors

A. Edge

B. Pin

XII. Advantages and disadvantages of common printed circuit board connectors

A. Edge connectors (Transparency #1)

1. Advantage--Inexpensive

2. Disadvantages

a. Require special gold finish on contactless resistance

b. Gold finished contacts wear off easily

c. Make good connections difficult to maintain when board warps

B. Pin connectors (Transparency #2)

1. Advantages

a. Do not need gold plating

b. Help prevent warping

2. Disadvantages

a. Bulky

b. Connections must be made individually by soldering or wire-wrapping

c. Require time-consuming installation

XIII. Characteristics of mounting printed circuit board assemblies (Transparency #3)

A. Assembly is usually a part of a much larger system

B. Drawer or printed circuit board rack is usually available

C. Assemblies have guides in order to slide board into connector and prevent board from touching connectors

INFORMATION SHEET

XIV. Design and layout procedures for a printed circuit board (Transparency #4)

A. Find design circuit to be fabricated

B. Plan circuit so that single-clad material may be used

C. Design circuit so that conductor intersections may be avoided

(NOTE: Place components so that they bridge conductors.)

D. Use a jumper when an undesired intersection is needed

E. Keep circuit conductors as wide as practically possible

(NOTE: Conductors, spacing between conductors, and spacing between conductors and edge of board should be a minimum of 1/32 of an inch. Spacing between edges of holes, and spacing between edges of holes and edges of boards should be a minimum of the thickness of the board material. Desirable spacing of termination points should be 1/10 of an inch, which is accepted as the standard throughout industry.)

XV. Manual steps in fabricating a printed circuit board

A. Transfer layout design onto copper surface

B. Centerpunch terminations through layout paper

C. Sketch or transfer design onto copper with carbon paper

(NOTE: Copper surface should be reasonably clean. If it is not clean, clean with steel wool or light abrasive cleaner, rinse, and thoroughly dry.)

D. Place circuit on copper side of printed circuit board, using resist ink, resist tape, and resist symbols

(NOTE: Tape should overlap terminations about 1/16 of an inch to stop etching solution from penetrating connection.)

E. Remove excess copper by rinsing printed circuit board in ferric chloride for about 15 to 20 minutes

(NOTE: Etchant time may be decreased by vigorous agitation and control of ferric chloride at a temperature of 120°F.)

F. Rinse printed circuit board under running water to remove ferric chloride

G. Remove resist tape, symbols, and ink

H. Rinse printed circuit board thoroughly and dry

I. Drill correct-sized holes for components being mounted

J. Insert components from side of printed circuit board opposite conductive material

INFORMATION SHEET

K. Solder

(NOTE: Use very small amounts of solder. See unit titled "Soldering Techniques.")

L. Clip component leads flush with solder connections

M. Check all conductor connections and conductors for correct continuity

XVI. Advantages of printed circuit boards

A. Often small due to conductor construction

B. Lighter in weight than other chassis

C. Reduce equipment downtime

(NOTE: Troubleshooting and repair is easy and fast due to finding faulty board and replacement. Printed circuit boards were originally developed as replaceable components. It soon was found that repair was relatively easy because there were no loose wires to short out during repair.)

D Increase system reliability

(NOTE: Printed circuit boards are not affected by shock as normal wiring circuits can be.)

E. Inexpensive to construct

XVII. Problems that may occur in printed circuit boards

A. Printed conductive material may lift from the board if excessive heat is applied

B. Conductive wiring may crack if board is bent excessively

C. Excess soldering iron wattage may burn up components or make soldering difficult because of small connection sizes and heat-sensitive components

XVIII. Methods of repairing printed circuit boards (Transparency #5)

A. Small crack--Locate crack in printed circuit board; lightly apply low-wattage soldering iron to point of repair; mend crack with small amount of solder

(NOTE: This method may change the circuit's current-carrying capabilities. For this reason, it is best to use the bridging method.)

B. Bridging--Place a short piece of bare copper wire across the crack in the printed circuit conductor; allow solder to flow along the complete length of the bare copper wire

(NOTE: Bare copper wire should extend at least 1/4 of an inch on each side of crack.)

INFORMATION SHEET

C. Large crack or broken board--Repair large areas by connecting a small-gauge wire to convenient terminal points on printed circuit board

(NOTE: Another method would be to drill holes in printed circuit board and add wire across gap.)

XIX. Methods of removing a bad component from a printed circuit board

A. Apply small-wattage soldering iron to component connection while lightly pulling on component lead; remove excessive solder with solder sucker or wire braid

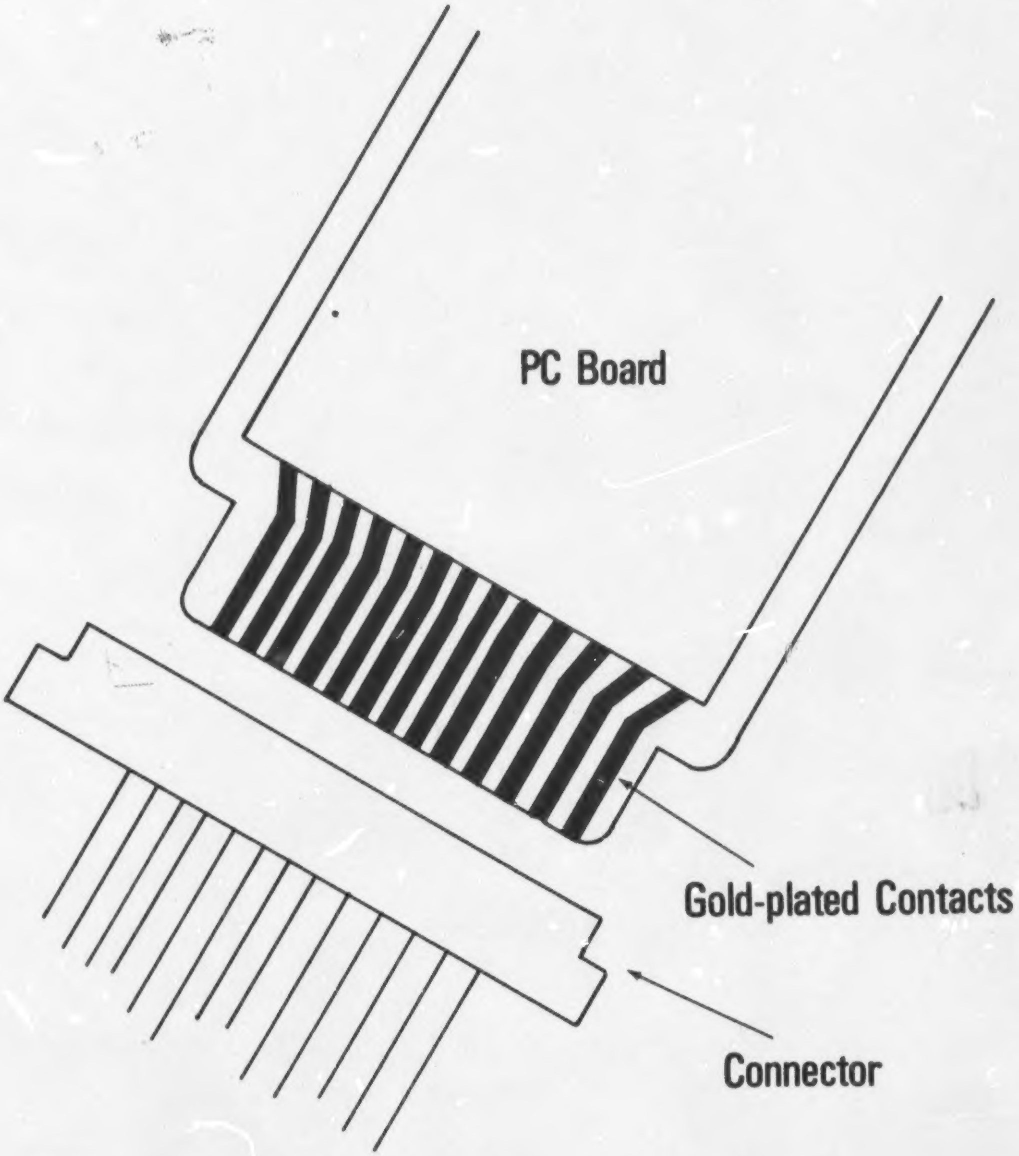
B. Break component in half with diagonal cutting pliers; solder new component to old leads

C. Use solder sucker or wire braid to remove solder; remove component

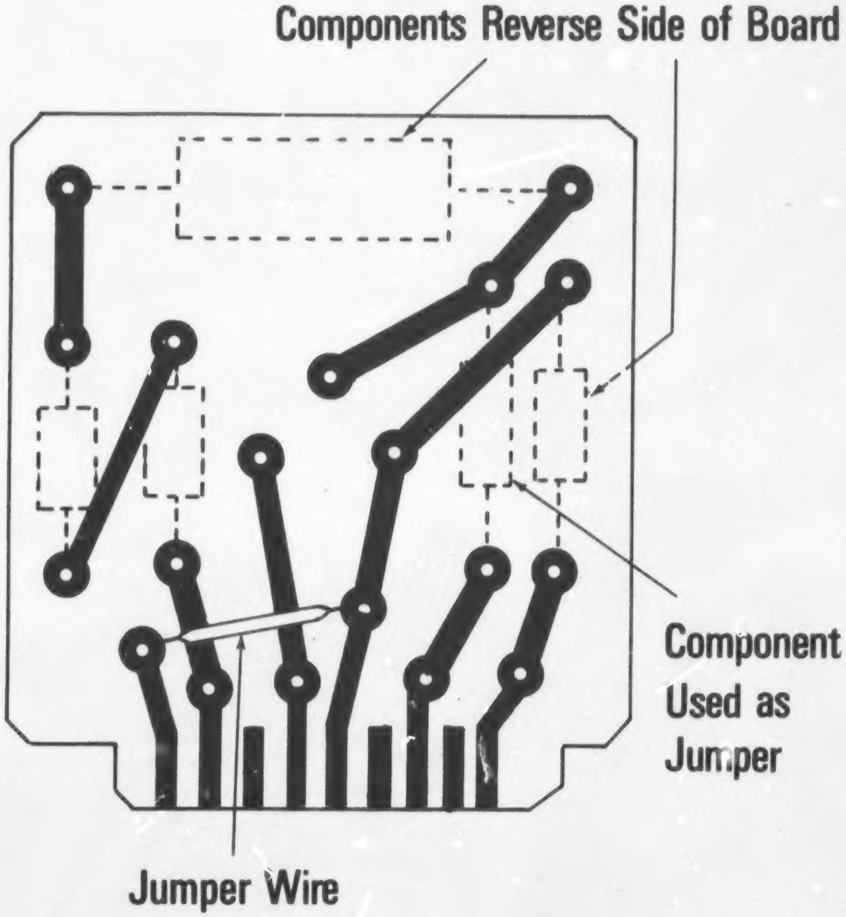
(NOTE: The most desirable method is to remove old component from board and replace with a new component.)

XX. Procedure for replacing a heat-sensitive component--Insert new component using heat sink between solder connection and heat-sensitive component

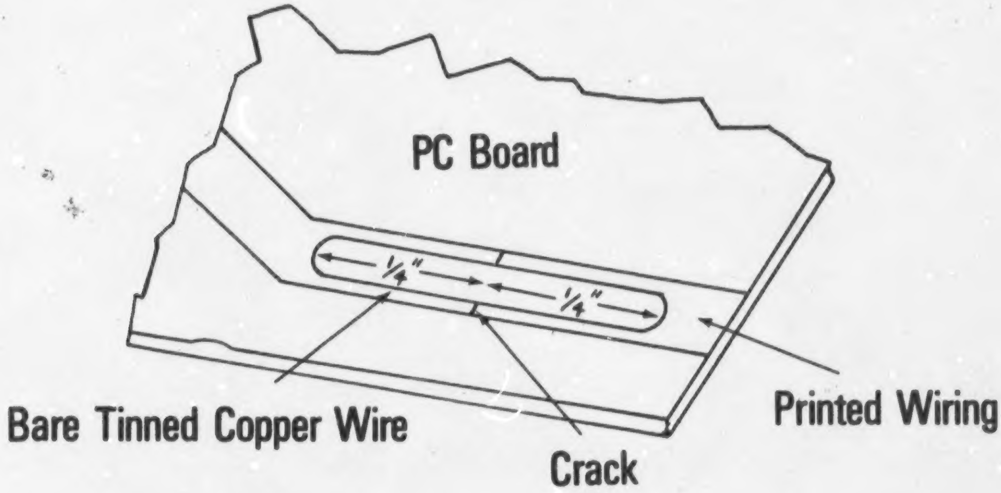
Edge Connector


PC Board
Gold-plated Contacts
Connector

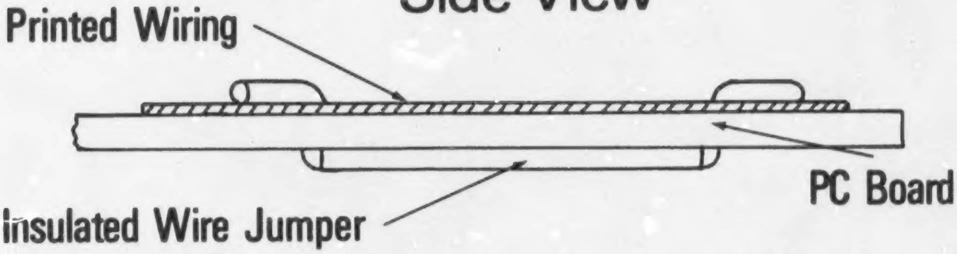
PC Board Layout


Components Reverse Side of Board
Component Used as Jumper
Jumper Wire

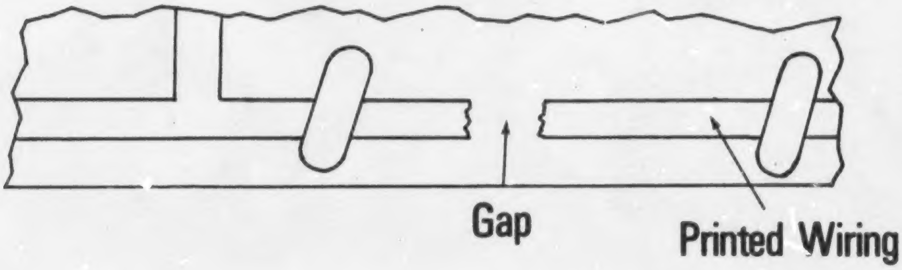
PC Board Repair Procedures


PC Board
1/4"
1/4"
Bare Tinned Copper Wire
Crack
Printed Wiring

Side View


Printed Wiring
PC Board
Insulated Wire Jumper

Top View


Gap
Printed Wiring

PRINTED CIRCUIT BOARDS
UNIT III

ASSIGNMENT SHEET #1--DESIGN A CIRCUIT LAYOUT FOR A PRINTED CIRCUIT BOARD

NAME ______________________________ SCORE ______________

Circuit layout must be used when fabricating a printed circuit board. This circuit may be obtained from many different sources. A circuit may be designed by you; a circuit may be taken from a magazine and the layout may be previously done; or a circuit may be copied from another printed circuit board.

Find a circuit, or design one yourself, and lay out for transfer to the PC board. Follow guidelines listed in the Information Sheet. When layout is completed, have the instructor check your work.

PRINTED CIRCUIT BOARDS
UNIT III

ANSWERS TO ASSIGNMENT SHEET

Assignment Sheet #1--Evaluated to satisfaction of instructor

PRINTED CIRCUIT BOARDS
UNIT III

JOB SHEET #1--TRANSFER A CIRCUIT LAYOUT TO A PRINTED CIRCUIT BOARD

I. Equipment and materials

   A. Printed circuit board to be fabricated

   B. Circuit layout design, approved by the instructor

   C. Punch

   D. Hammer

II. Procedure

   A. Check copper coating of PC board

   (NOTE: If not clean, clean board with steel wool or light abrasive cleanser; rinse in clean water; dry thoroughly.)

   B. Place sketch of circuit on PC board by sketching, or use carbon paper to transfer circuit

   C. Centerpunch terminals through circuit layout paper

   (NOTE: Have instructor inspect PC board.)

   D. Put equipment and materials away

PRINTED CIRCUIT BOARDS
UNIT III

JOB SHEET #2--PREPARE A PRINTED CIRCUIT BOARD FOR ETCHING

I. Equipment and materials

A. Printed circuit board with circuit sketch

B. Resist ink

C. Resist symbols

D. Resist tape

II. Procedure

A. Recheck PC board fabricated in Job Sheet #1 for correct circuit design

B. Place resist symbols on PC board where indicated by sketch

C. Use resist tape for all conductors

(NOTE: Be sure tape and symbols overlap approximately 1/16 of an inch. Have instructor inspect PC board.)

D. Put equipment and materials away

PRINTED CIRCUIT BOARDS
UNIT III

JOB SHEET #3--ETCH A PRINTED CIRCUIT BOARD

I. Equipment and materials

A. PC board--With circuit layout in resist tape, symbols, and ink

B. Etching tray

C. Etchant solution

D. Rubber apron

E. Plastic tweezers

II. Procedure

(CAUTION: Use caution when using etchant. Rinse immediately if etchant contacts skin. It can cause irritation to skin and stain clothing.)

A. Place PC board in etchant tray

B. Pour etchant solution carefully into tray

C. Agitate solution over PC board by carefully rocking tray

(NOTE: Etching will occur in approximately 15-20 minutes. Time may be decreased if solution is kept at a temperature of 120°F.)

D. When all excess copper has been removed from PC board, rinse board thoroughly under running water

E. Remove resist tape

F. Rinse under running water and dry

(NOTE: Have instructor inspect PC board.)

G. Put equipment and materials away

PRINTED CIRCUIT BOARDS
UNIT III

JOB SHEET #4--INSTALL COMPONENTS ON A PRINTED CIRCUIT BOARD

I. Equipment and materials

- A. PC board with circuit
- B. Electronic components to be installed
- C. 1/4-inch electric drill
- D. Drill bits--Size of component conductors
- E. Solder--60/40
- F. Soldering iron--25-35 watts
- G. Heat sink
- H. Long-nose pliers
- I. Diagonal cutting pliers
- J. Safety goggles

II. Procedure

- A. Put on safety goggles
- B. Drill holes in PC board for all components

  (NOTE: If punching or shearing is to be done, PC board must be heated to approximately 100-125°F.)

- C. Clean with steel wool or scrub with fine abrasive cleaner
- D. Solder components to PC board

  (NOTE: PC board can safely be heated to 500°F for approximately 5 seconds. Heat connection only to point where solder will flow. Have instructor inspect PC board.)

- E. Put equipment and materials away

PRINTED CIRCUIT BOARDS
UNIT III

JOB SHEET #5--MAKE CONTINUITY CHECKS OF A PRINTED CIRCUIT BOARD

I. Equipment and materials

A. Printed circuit board

B. Magnifying glass

C. Multimeter

II. Procedure

A. Put PC board under powerful magnifying glass

B. Inspect for cracks, open conductors, or other abnormal conditions

C. Check conductors with multimeter

(NOTE: Do not measure across heat-sensitive components such as diodes or transistors. Have instructor check printed circuit board.)

D. Put equipment and materials away

PRINTED CIRCUIT BOARDS
UNIT III

JOB SHEET #6--MAKE PRINTED CIRCUIT BOARD REPAIRS

I. Equipment and materials

- A. Printed circuit board--Set up by your instructor
- B. Magnifying glass
- C. Multimeter
- D. Soldering iron--25 to 35-watt
- E. Solder--60/40
- F. Wire
- G. Diagonal cutting pliers
- H. Wire strippers

II. Procedure

- A. Check for troubles, and repair according to the three types of troubles: small cracks, small amounts of missing conductor material, or large amounts of missing conductor material

  (NOTE: Use your Information Sheet for reference. Have your instructor check repairs.)

- B. Put equipment and materials away

PRINTED CIRCUIT BOARDS
UNIT III

TEST

NAME ______________________________ SCORE _______________

1. Match terms associated with printed circuit boards to their correct definitions. Write the correct numbers in the blanks.

_____a. Chemical solution which removes excess copper coating from printed circuit boards

_____b. Process in which printed circuit board components are all placed on the circuit board, which is then moved over a wave of molten solder, thus soldering all connections simultaneously

_____c. Very fine wire braid used to remove solder from solder points by placing solder braid between soldering iron and solder, thus soaking up solder and leaving the connection bare

_____d. Tool which draws hot solder from an electronic connection; may be operated by hand or by electricity

_____e. Plastic wedge attached to printed circuit boards; used to remove tightly clamped circuit boards

_____f. Device attached to printed circuit boards; used to remove board from mounting

_____g. Process using wire braid to remove solder from solder connections; flow of solder under the insulation of covered wire

_____h. Adjustable clamping device mounted on a base or stand to hold a printed circuit board during repair

_____i. Adapter that increases connector length to make the printed circuit board visible for in-circuit work

_____j. Conductive material on only one side of a circuit board

_____k. Conductive material bonded to printed circuit board

_____l. Tool having a heating element to melt solder

1. Wave soldering
2. Jig
3. PC board handles
4. Ammonium persulfate
5. Solder sucker
6. Wicking
7. Wire braid
8. Board ejector
9. Single-clad
10. Clad
11. Extender board
12. Soldering iron

TEST

_____m. Liquid deposited onto a copper-clad material to prevent copper conductive material from being etched away

_____n. Pattern of conductors mounted on an insulated base material to provide the interconnection of components to make an electrical circuit

_____o. Plastic, phenolic, or fiberglass material, 1/16 to 1/18 of an inch thick, onto which a circuit has been printed with copper or silver conductive material, and electronic components have been installed

_____p. Process where circuit is drawn on paper, photographed, and then photographically transferred onto phenolic board

_____q. Plastic material (thermosetting resin) which becomes permanently hardened when subjected to heat; originally known as Bakelite®; used for printed circuit board construction

_____r. Metal tool used to radiate heat away from the components when soldering or desoldering

_____s. Solution used to remove excess copper coating from printed circuit boards

_____t. Tray used to rinse excess copper from printed circuit boards

_____u. Tool with a fork, hook, brush, knife, or reamer; used when soldering or desoldering conductors

13. Resist ink
14. Printed wiring
15. Phenolic board
16. Printed circuit board
17. Photoetching
18. Etching tray
19. Heat sink
20. Soldering aid
21. Ferric chloride

2. Match abbreviations associated with printed circuit boards to their correct definitions. Write the correct numbers in the blanks.

_____a. Switch

_____b. Fuse

_____c. Test point

_____d. Light-emitting diode

_____e. Integrated circuit

_____f. Terminal board

_____g. Transformer

1. LED
2. S or Sw
3. TP
4. TB
5. IC
6. F
7. T

TEST

_____ h. Vacuum tube

_____ i. Diode

_____ j. Transistor

_____ k. Inductor

_____ l. Capacitor

_____ m. Resistor

_____ n. Printed wiring

_____ o. Printed circuit board

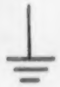
_____ p. Printed circuit

8. R
9. PC
10. V
11. C
12. L
13. PCB
14. Q
15. PW
16. D

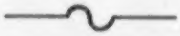
3. Identify symbols associated with printed circuit boards. Write the correct names in the blanks below each symbol.

Resistor
Capacitor
Inductor
Transistor
Fuse
Diode

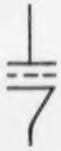
Tube
Ground
Switch
Light-emitting diode
Transformer



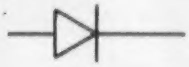
a. ______________________________



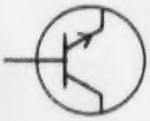
b. ______________________________



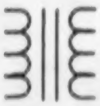
c. ______________________________



d. ______________________________

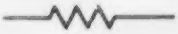


e. ______________________________

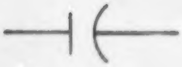


f. ______________________________

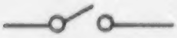
TEST



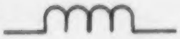
g. ______________________



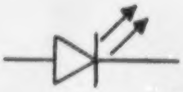
h. ______________________



i. ______________________



j. ______________________



k. ______________________

4. List materials needed to fabricate a printed circuit board.

a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

f. ______________________

g. ______________________

h. ______________________

i. ______________________

j. ______________________

TEST

5. List three materials used in constructing a printed circuit board.

   a. ____________________

   b. ____________________

   c. ____________________

6. Name types of printed circuit boards.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

   e. ____________________

7. Distinguish between mechanical and chemical methods of transferring circuit layout to a single-sided, printed circuit board. Write in the appropriate blanks an "M" for mechanical technique, or a "C" for chemical technique.

   _____a. Photographic

   _____b. Spraying

   _____c. Silk-screening

   _____d. Stamping

   _____e. Embossing

   _____f. Printed

8. Arrange in order steps in transferring circuit layout to a double-sided, printed circuit board. Write a "1" for the first step, a "2" for the second step, and so on.

   _____a. Electro-deposit copper on the board and on all sides of the holes

   _____b. Drill holes, as indicated by layouts

   _____c. Strip away resist, leaving the circuit pattern on both sides of the printed circuit board

   _____d. Design two layouts, one for each side

   _____e. Apply negative resist to areas indicated by layouts

TEST

9. Select from the list below specifications for mounting components on a printed circuit board. Write an "X" in the blank before each correct answer.

______a. Sockets and connectors should be mounted as close to board as possible

______b. Heat sinks should always be used for heat-sensitive components

______c. Component markings should be done in blue ink

______d. Component markings should be clearly visible

______e. Always use a high-wattage soldering iron to solder heat sensitive components to board

______f. Components should be mounted directly on printed circuit board or as close to board as possible

______g. Heavy components should have additional support against shock and vibration

10. Select from the following list conformal coating characteristics of a printed circuit board. Write an "X" in the blank before each correct answer.

______a. Leaves a thick, rough film over the printed circuit board, due to solvent evaporating

______b. Made from silicone, epoxy, polyurethane, varnish, or lacquer dissolved in a solvent

______c. Doubled around connectors to prevent touching

______d. Leaves thin, rough film over the printed circuit board, due to solvent evaporating

______e. Placed over the complete printed circuit board assembly

11. List common types of printed circuit board connectors.

a. ______________________________

b. ______________________________

12. Select from the following list advantages and disadvantages of common printed circuit board connectors. Write in the appropriate blanks an "A" for advantage, and a "D" for disadvantage.

______a. Pin connectors do not need gold plating

______b. Edge connectors are inexpensive

______c. Edge connectors require special gold finish on contactless resistance

______d. Pin connectors are bulky

TEST

_____e. Pin connectors require time-consuming installation

_____f. Edge connectors have gold finished contacts which wear off easily

_____g. Edge connectors make good connections difficult to maintain when board warps

_____h. Pin connectors help prevent warping

_____i. Pin connectors require that connections must be made individually by soldering or wire-wrapping

13. Discuss characteristics of mounting printed circuit board assemblies.

____

____

____

____

____

14. List design and layout procedures for a printed circuit board.

a. ____

b. ____

c. ____

d. ____

e. ____

15. Arrange in order manual steps in fabricating a printed circuit board. Write a "1" for the first step, a "2" for the second step, and so on.

_____a. Remove excess copper by rinsing printed circuit board in ferric chloride for about 15 to 20 minutes

_____b. Centerpunch terminations through layout paper

_____c. Sketch or transfer design onto copper with carbon paper

_____d. Transfer layout design onto copper surface

_____e. Place circuit on copper side of printed circuit board, using resist ink, resist tape, and resist symbols

TEST

_____f. Check all conductor connections and conductors for correct continuity

_____g. Drill correct-sized holes for components being mounted

_____h. Rinse printed circuit board under running water to remove ferric chloride

_____i. Insert components from side of printed circuit board oppositve conductive material

_____j. Rinse printed circuit board thoroughly and dry

_____k. Solder

_____l. Remove resist tape, symbols, and ink

_____m. Clip component leads flush with solder connections

16. Select from the following list advantages of printed circuit boards. Write an "X" in the blank before each correct answer.

_____a. Often large due to connections

_____b. Inexpensive to construct

_____c. Heavy because of mountings

_____d. Increase system reliability

_____e. Often small due to conductor construction

_____f. Reduce equipment downtime

_____g. Lower overall dependability of system

_____h. Lighter in weight than other chassis

17. List problems that may occur in printed circuit boards.

a. ____

____

b. ____

____

c. ____

____

TEST

18. Match methods of repairing printed circuit boards to their correct descriptions. Write the correct numbers in the blanks.

______a. Place a short piece of bare copper wire across the crack in the printed circuit conductor; allow solder to flow along the complete length of the bare copper wire

______b. Locate crack in printed circuit board; lightly apply low-wattage soldering iron to point of repair; mend crack with small amount of solder

______c. Repair large areas by connecting a small gauge wire to convenient terminal points on printed circuit board

1. Bridging
2. Small crack
3. Large crack or broken board

19. Describe methods of removing a bad component from a printed circuit board.

20. Explain the procedure for replacing a heat-sensitive component.

(NOTE: Test questions 21 and 22 are assignment and job sheets. They are an important part of this unit. If they have not been completed, check with your instructor.)

21. Design a circuit layout for a printed circuit board.

22. Demonstrate the ability to

    a. Transfer a circuit layout to a printed circuit board.

    b. Prepare a printed circuit board for etching.

    c. Etch a printed circuit board.

    d. Install components on a printed circuit board.

    e. Make continuity checks of a printed circuit board.

    f. Make printed circuit board repairs.

PRINTED CIRCUIT BOARDS
UNIT III

ANSWERS TO TEST

1. a. 4
b. 1
c. 7
d. 5
e. 8
f. 3
g. 6
h. 2
i. 11
j. 9
k. 10
l. 12
m. 13
n. 14
o. 16
p. 17
q. 15
r. 19
s. 21
t. 18
u. 20

2. a. 2
b. 6
c. 3
d. 1
e. 5
f. 4
g. 7
h. 10
i. 16
j. 14
k. 12
l. 11
m. 8
n. 15
o. 13
p. 9

3. a. Ground
b. Fuse
c. Tube
d. Diode
e. Transistor
f. Transformer

ANSWERS TO TEST

g. Resistor

h. Capacitor

i. Switch

j. Inductor

k. Light-emitting diode

4. a. Board with conductive coating

b. Resist ink

c. Resist symbols

d. Resist tape

e. Ferric chloride or equivalent chemical

f. Etching tray

g. 25 to 35-watt soldering iron

h. Drill motor and drills, sized according to conductor diameter of components

i. Various components for circuit being built

j. Circuit layout or design to be placed on printed circuit board

5. Answer should include any three of the following

a. Plastic

b. Fiberglass

c. Paper-base phenolic

d. Plastic phenolic

e. Glass epoxy

6. a. Flexible boards

b. Rigid boards

c. Single-sided

d. Double-sided

e. Laminated

ANSWERS TO TEST

7. a. C
   b. M
   c. C
   d. M
   e. M
   f. C

8. a. 4
   b. 2
   c. 5
   d. 1
   e. 3

9. a, b, d, f, g

10. b, d, e

11. a. Edge
    b. Pin

12. a. A
    b. A
    c. D
    d. D
    e. D
    f. D
    g. D
    h. A
    i. D

13. Discussion should include
    a. Assembly is usually a part of a much larger system
    b. Drawer or printed circuit board rack is usually available
    c. Assemblies have guides in order to slide board into connector and prevent board from touching connectors

14. a. Find design circuit to be fabricated
    b. Plan circuit so that single-clad material may be used
    c. Design circuit so that conductor intersections may be avoided
    d. Use a jumper when an undesired intersection is needed
    e. Keep circuit conductors as wide as practically possible

ANSWERS TO TEST

15. a. 5
    b. 2
    c. 3
    d. 1
    e. 4
    f. 13
    g. 9
    h. 6
    i. 10
    j. 8
    k. 11
    l. 7
    m. 12

16. b, d, e, f, h

17. a. Printed conductive material may lift from the board if excessive heat is applied
    b. Conductive wiring may crack if board is bent excessively
    c. Excessive soldering iron wattage may burn up components or make soldering difficult because of small connection sizes and heat-sensitive components

18. a. 1
    b. 2
    c. 3

19. Description should include
    a. Apply small-wattage soldering iron to component connection while lightly pulling on component lead; remove excessive solder with solder sucker or wire braid
    b. Break component in half with diagonal cutting pliers; solder new component to old leads
    c. Use solder sucker or wire braid to remove solder; remove component

20. Insert new component using heat sink between solder connection and heat-sensitive component

21. Evaluated to satisfaction of instructor

22. Performance skills evaluated to satisfaction of instructor